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PRELIMINARY SOIL AND GROUNDWATER CHARACTERIZATION STUDY AT THE CFAD DUNDURN EXPLOSIVES FACILITY (SASKATCHEWAN)

Final Report

Presented to
National Defence Department
Defence Research Establishment Valcartier
Energetic Materials Division
Chemistry and Environment Section
P.O. Box 8800 Courcelette, Québec
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Attention: Dr. Guy Ampleman

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October 1996

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1. Introduction

Defence Research Establishment Valcartier mandated INRS-Géoressources to supervise a preliminary characterization study of the explosive burning site at CFAD Dundurn, Saskatchewan. High energetic materials have been burned at that site for more than 25 years. The environmental impact of this activity on soil and groundwater is unknown and this preliminary characterization study was undertaken in september 1995. More than 16 wells were installed on site at 8 different locations. In addition 72 soil samples and 31 groundwater samples were taken to investigate the site. This report includes technical informations on geology, piezometry (water levels) and groundwater flow, soil and groundwater sampling, energetic materials (RDX, HMX and TNT) analysis and concentrations in soils and groundwater. Finally, conclusions and recommendations are made to help the Ministry of defence better orient future work which would help the management of that site.

2. Objectives and work responsabilities

The objective of this study was to characterize the open burning/open detonation (OB/OD) area of the National Defence training area in CFAD Dundurn, Saskatchewan. This characterization study includes drilling and well installation, groundwater flow and velocity determination, soil and groundwater sampling, soil properties evaluation (grain-size distribution, composition, hydraulic conductivity), RDX and TNT content in groundwater and soil.

Members of INRS-Géoressources, Golder Associates Ltd. employees, National Defence scientists from Valcartier and members of the CFAD Dundurn were involved in field characterization activities. Drilling and observation well installation were achieved by Golder Associates Ltd. under the supervision of INRS-Géoressources members (Golder Associates Ltd., 1995). INRS-Géoressources was responsible of soil and grounwater sampling, permeability tests, data interpretation and writting the final report. Soil and groundwater sampling were done with the help of National Defence scientists, and members of the CFAD Dundurn helped perform the permeability tests. RDX, HMX and TNT in soil and groundwater samples were analyzed by chemists of the Defence Research Establishment in Valcartier, Québec.

3. Location and geology

The CFAD Dundurn is located 30 km south of Saskatoon, Saskatchewan. The burning area is located on the CFAD Dundurn base at 3.5 km north-west of the Dundurn camp. Topography is typical of an eolian environment. Surficial sediments are eolian plain and eolian dune (SRC, 1986) as observed in boreholes and are underlain by fluviolacustrine sediments. Two classes of grain-size curves are observed (Appendix 1). 1) a poorly sorted sand with a mean grain diameter (d_{50}) which varies between 40 µm to 70 µm corresponding to a very fine sand; and 2) a well sorted fine sand (d_{50} between 100 µm and 150µm) which corresponds to layered sand deposits The proportion of silt-size

material in sand varies from 1 to 10%. The sand is iron stained above the water table which indicates an oxydizing environment. Layers of fine coal fragments were noticed in the sand between 6 and 7 m depth (around elevation 495 and 494 m). The underlying unoxydized till formations as well as the underlying cretaceous rock formation were not drilled. The Bearpaw rock formation in the area is defined as a gray, noncalcareous silt and clay (Christianson and Meneley, 1971).

4. Hydraulic head and groundwater flow

The hydraulic conductivity was evaluated using downward slug tests which were interpreted using the Hvorslev (1951) method. The values measured vary by one order of magnitude i.e. from 1.7×10^{-5} to 1.0×10^{-4} m/s which is usual in stratified sediments (Appendix 2). The geometric mean hydraulic conductivity (5.0×10^{-5} m/s) is typical of a fine sand (Freeze and Cherry, 1979). The mean hydraulic conductivity of the sand was also evaluated from the 10% passing grain diameter (d10) obtained from the grain-size curve (Hazen relation in Freeze and Cherry (1979)). The estimated average permeability (2.5×10^{-5} m/s) from grain-size curves (Appendix 3) agrees with the mean hydraulic conductivity estimated from slug tests. Because there is no low permeability sediment layers on top of the sand unit, the aquifer is unconfined and is vulnerable to groundwater contamination from the soil surface. The water table at the site is located between 5 and 7 m depth which corresponds to an elevation close to 505 m. The horizontal hydraulic gradient (the slope of the water table) is 0.0005 m/m and groundwater flows from east to west (Figure 1). According to the following equation, assuming a porosity of 0.3 for the sand, groundwater flows with an estimated average velocity of 2.6 m/year. Assuming that groundwater flows at the same velocity between the burning area and the closest discharge area (Indian lake), it would take approximately 2000 years to reach Indian lake located at 5700 m west. No significant vertical gradient is observed in the wells. So, there is no significant upward and downward flow in the saturated zone.

$$v = Ki/n$$

where v is the mean groundwater velocity
K is the hydraulic conductivity m/s
i is the horizontal hydraulic gradient m/m
n is the porosity (pore volume fraction of the total volume)

Since most of the wells were aligned to follow potential contamination in soil and groundwater from the burning area, it is recommanded to drill nine more sites to confirm groundwater flow directions on a larger area. The hydraulic gradient is so small that it could shift with seasons and the groundwater flow direction needs to be established more firmly.

5. Soil and groundwater sampling

Sixteen (16) boreholes were drilled between 6 m and 15 m deep with a 4.5 inch inside diameter hollow stem auger. Records of boreholes from Golder Associates Ltd. (1995) are included in Appendix 4. Each drilled site is identified on maps with letter P followed by a number indicating the site. Sediments were sampled continuously at each 1.5 m interval with a 2 inch split spoon in eight boreholes. Continuous records of soil conditions were made. All drilling and sampling equipments were decontaminated (washed with warm water and rinsed with acetone, hexane, acetone and distilled water) to reduce cross-contamination between samples and boreholes. Seventy two (72) soil samples were taken and sample recovery was very good most of the time (between 60% and 100%) and there were very few unrecovered samples (2) and a few low recovery samples (14) from 10% to 50%.

One observation well was installed in each borehole. Wells are identified on maps with letters A and B indicating respectively the deep well (A close to 15 m depth) and the shallow well (B close to 6 m depth). Groundwater was sampled using a Waterra pump in november 1995 and in april 1996. To obtain a representative groundwater sample from the aquifer, a volume of groundwater corresponding to 5 times the volume of water inside the tubing and around the screen and the sand filter was removed from the observation well. All observation wells were sampled in november 1995 and in april 1996.

6. RDX, HMX and TNT analyses in sediments and groundwater

RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine) and TNT (2,4,6-trinitrotoluene) concentrations in soils were determined in the field on every soil samples (except for P-8, with one sample out of two) with the DTECH on-site technique and on one sample out of two in the laboratory by the HPLC technique (EPA SW-846 Method 8330). All results of TNT, RDX and HMX analyses in soil samples are included in tables of Appendix 5. HMX (octohydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine) concentrations in soil as well as TNT concentrations in groundwater were determined only in the laboratory by the HPLC technique (EPA SW-846 Method 8330). All results of TNT, RDX and HMX analyses in groundwater samples are compiled at the Appendix 6.

RDX and TNT were extracted from soils with acetone as described in the DTECH soil extraction Pac (TK-1001S-1). The DTECH method for TNT and RDX determination in soils utilizes immunoassay technology. The minimum detection limit (MDL) of the test for RDX and TNT in soil is 0.5 mg/kg (ppm). For TNT, the minimum quantitative limit in a soil sample occurs at a concentration of 0.6 ppm.

In EPA SW-846 Method 8330, RDX, TNT and HMX in soils are extracted with acetronitrile and estimation of these organic compounds concentrations and identification of their metabolites are made by HPLC with a minimum detection limit of 0.2 mg/kg (ppm). RDX, HMX and TNT concentrations in groundwater were determined by HPLC with a MDL of 0.2 μg/L (ppb).

7.0 RDX, HMX and TNT criteria and concentrations in soils and groundwater

7.1 Explosives criteria in groundwater

A groundwater quality criteria may vary as a function of aquifer classification, groundwater utilization, human health risk or ecotoxicological risk, connection of the contaminated groundwater with surface water or with other aquifer of higher class, and contaminant source location. The Ministry of defence must study or evaluate what groundwater standard should be applied at the Dundurn site. For the moment, because no such prior evaluation was done, we propose the use of a drinking water guideline based on human health (Table 1). Drinking water guidelines exist for TNT and RDX. The most recent data suggest a quality guideline for TNT in groundwater at 2.0 ppb. An Ontario guideline based on a AWWA (American Water Work Association) reference of 1983 proposed 5 ppb. We proposed the 2 ppb criteria because it is conservative and is related to recent litterature. EPA published a guideline for RDX in groundwater in 1992. This very strict criteria of 0.3 ppb was based on health advisory and should be used as a preliminary guideline to see extent of groundwater contamination by this high explosive compound. No quality guideline was available for HMX concentrations in groundwater.

Table 1. Drinking water guideline based on health advisory for TNT and RDX

Drinking water guideline	TNT concentration in groundwater (µg/L)	RDX concentration in groundwater (µg/L)	HMX concentration in groundwater (µg/L)
	2.0[a] 5.0[b]	**0.3**[c]	no data available

[a] IRIS data bank (revised standard in 1993)
[b] Environment Ontario, 1989 (Emergency limit for long-term consumption)
[c] Mc Lellan et al., 1992

7.2 Explosives concentration in groundwater

In the fall of 1995 and the spring of 1996, TNT was detected in groundwater of the shallow well (B) of the P-3 site (the main burning area) but not in the deep well (A) (Figure 2). Concentrations of TNT in this well (2.7 and 1.9 ppb) are low but close to the drinking water criteria of 2 ppb. In fall 1995, TNT was detected at a value close to 2 ppb in groundwater in the deep wells of two upgradient sites, P-1 and P-2, but was not detected in the spring of 1996. In the fall, a groundwater sample from the shallow well (B) of the downgradient sampling site P-6 had a measured TNT concentration above 2 ppb but again was not contaminated in the spring. The available data indicate that groundwater contamination by TNT is not persistent (appears and desapears with seasons) and seems to be limited to the burning area.

RDX concentrations measured in groundwater are significant (80-120 ppb) in the shallow well (B) of P-3B in the main burning area (Figure 3) and are persistant throughout seasons. RDX concentrations in groundwater decrease significantly with depth to reach the 5 ppb in the deep well (A). Elsewhere in the burning area, P-4 shows a lower level of RDX in groundwater. A RDX concentration in groundwater which decreases with depth is also observed at this site (from 4.5 ppb to 2.5 ppb). The surronding sites (P-2 and P-5) have also detected RDX in groundwater but with concentrations less than 2 ppb. In the same way, the downgradient site P-6 showed 2 ppb detected in both levels only last fall. Surprisingly, the upgradient site P-1 has persistant RDX concentrations in groundwater close to 5 ppb in both levels.

Because we dont know the extent of groundwater contamination by RDX, especially from the main burning area (site P-3), we propose to drill additonnal wells downgradient. Proposed location of future monitoring wells are shown on Figure 4. To better understand RDX and TNT circulation and transformation in groundwater we propose also to install two succion lysimeters in the vadose zone in the main burning area. The lysimeters could indicate the concentration of RDX and TNT in the water held in the soil under the burning areas prior to mixing with the underlying groundwater.

A false positive have occured in the groundwater sample of the shallow well of P-7. This can be explained by a probable cross-contamination with the drilling equipment. This assumption could be verified with an additionnal groundwater sampling If RDX and HMX are still present in P-7 after this sampling, an upgradient well should be installed to verify groundwater flow in this area.

HMX was undetected in most of the sampled wells (Figure 5). Concentrations of HMX in wells of the main burning area increase with depth going from 1 ppb near the water table to 4 ppb at depth. The same trend is observed with the neighbord site P-4. HMX seems not to be used, persistent or mobile in groundwater since no detected concentrations are observed in the downgradient wells of the main burning area (P-5, P-6 and P-8) Since no drinking water standards are available for this organic compound and the concentrations detected are very low, no specific recommendations are made for this explosive.

7.3 Explosives criteria in soil

A soil quality criteria may vary as a function of human health risk or ecotoxicological risk. The Ministry of defence must study or evaluate which soil criteria should be applied at the Dundurn site. For the moment, because no such evaluation was done, we propose to use existing soil criteria based on human health.

Soil criteria were calculated, based on human health, by Daniels and Knezovich (1994) for TNT, RDX and HMX. They evaluated concentrations in soil for carcinogenic and noncarcinogenic compounds. This study, which uses GEOTOX for criteria calculation, cannot be applied at the local scale (J.-P. Trépanier, personnal communication). However, it gives an idea of the relative toxicity of these compounds.

TNT and RDX are possible human carcinogens. The criteria for TNT and RDX in soil (for a 10^{-6} excess cancer risk) presented in Table 2 suggest that land contaminated at concentrations above 2.4 ppb and 0.35 ppb respectively, will need to be cleaned up. The very low level of excess cancer risk used in the calculation of these criteria is unrealistic and unsignificant compared to the 0.3 background cancer risk in the population. A value of 10^{-4} is more likely to represent the level of risk applied and allowed in our society. U.S. EPA., American policy agencies and Québec ministry of environment are proposing and evaluating the possibility to use 10^{-4} or 10^{-5} as potentially acceptable level of risk in environmental criteria calculation (U.S. EPA, 1991). For a 10^{-4} levels of risk, soil criteria of 0.24 ppm and 0.035 ppm for TNT and RDX respectively would be recommended.

If further toxicological studies show that these compounds are not human carcinogens, then the levels for cleanup would be the ones related to the hazard index: i.e. 0.037 ppm and 0.12 ppm for TNT and RDX respectively. Selecting the more restrictive criteria calculated based on the 10^{-4} level of risk and the hazard index, we obtain 0.037 ppm for TNT and 0.035 ppm for RDX.

HMX has inadequate data on carcinogenecity or no evidence of carcinogenecity. The criteria for HMX in soil (2.2 ppm) is based on the hazard index because HMX is not classifiable as a human carcinogen.

Trépanier and Ayotte (1991) calculated generic soil criteria for TNT based on human health. They evaluated criteria based on potential land use (Table 3). Concentrations of contaminant in soil lower than B criteria allow residential use whereas a land where concentrations of contaminant are lower than C criteria may be used for industrial development. As shown for TNT, criteria may change depending on the proposed land use. The B criteria for TNT, calculated by Trépanier and Ayotte (1991), corresponds to the selected criteria by Daniels and Knezovich (1994).

Table 2. Concentration of TNT, RDX and HMX in soil above which cleanup would be recommanded based on human risk (Daniels and Knezovich, 1994)

Potentially acceptable level of risk and the acceptable index for noncancinogenic hazard	TNT concentration in soil (mg/kg)	RDX concentration in soil (mg/kg)	HMX concentration in soil (mg/kg)
10^{-6} excess cancer risk	0.0024	0.00035	n/a
10^{-4} excess cancer risk	0.24	**0.035**	n/a
hazard risk	**0.037**	0.12	**2.2**

Table 3. TNT concentrations in soil and potential land use based on human risk (Trépanier and Ayotte, 1991)

Potential Land Use	TNT concentration in soil (mg/kg)
Residential (B criteria)	**0.04**
Industrial (C criteria)	1.7

7.4 Explosives concentrations in soil

TNT concentrations in soil are low (Figure 6) but the minimum detection limit (0.2 ppm) of the analatycal method used is one order of magnitude higher than the selected soil criteria (0.037 ppm) which makes impossible the estimation of the contaminated volume of soil. TNT concentrations in groundwater of some wells are not linked to TNT concentrations in soils (P-3B, P-4A P-6B P7-B). For a better interpretation of this effect, we recommend to analyze soil samples (P-3 15-20, 35-40, 45-50; P-6 25-30, 30-35; P-7 15-20) with the more precise HPLC technique.

RDX was not detected in soil (Figure 7) except at P-4 where 1 3 ppm was analysed by HPLC between 40 and 45 feet depth. This zone contaminated with RDX does not correspond to the major groundwater contamination by RDX at the Dundurn site indicating that soil and groundwater contamination are curiously not directly related. The minimum detection limit (0.2 ppm) of the HPLC method used is one order of magnitude higher than the selected soil criteria (0.035 ppm) which makes impossible the estimation of the contaminated volume of soil by RDX.

No contamination of soil was detected for HMX (Figure 8). HMX concentrations in soil are undetected or are detected at two sites at 0.4 ppm which is far below the proposed 2.2 ppm criteria.

We recommend to the Ministry of defence to make a risk analysis based on health or ecotoxicological data to generate site specific criteria for TNT and RDX in soil and groundwater. From this evaluation, it will be decided if more precise soil analyses are needed. However, the extent of groundwater contamination by RDX and the groundwater flow direction must be better defined before performing the risk analysis. Groundwater usage in the area as well as aquifer classification should also be better known. More wells and a few succion lysimeters must be installed to better understand the behavior of TNT and RDX in soil and groundwater at the site.

8. Conclusions and recommendations

A preliminary characterization study of soil and groundwater has been done at the Dundurn site The explosive burning area is located on an unconfined fine sand aquifer having a mean hydraulic

conductivity of 5 x 10^{-5} m/s. The water table is located 6 m deep. Groundwater flows from east to west with a mean velocity of 3 m/year. HMX, RDX and TNT have been detected in groundwater and soil. RDX concentrations in groundwater of the main burning area is high compared to available contamination criteria. However RDX contamination extent outsite the burning area is unknown.

HMX was undetected in most of the sampled wells. HMX seems not to be used, persistent or mobile in groundwater since no detected concentrations are observed in the downgradient wells of the main burning area (P-5, P-6 and P-8). Since no drinking water standards are available for this organic compound and the concentrations detected are very low, no specific recommendations are made for this explosive.

TNT was detected in groundwater of the shallow well of the main burning area and periodically in other wells. The available data show that groundwater contamination by TNT is not persistent (appears and desapears with seasons) and seems to be limited to the burning area.

TNT concentrations in soil are low but the minimum detection limit of the analytical method used is one order of magnitude higher than the selected soil criteria which makes impossible the estimation of the contaminated volume of soil. TNT concentrations in groundwater of some wells are not linked to TNT concentrations in soils.

RDX was not detected in soil except in one soil sample at P-4. This RDX contaminated zone does not correspond to the major groundwater contamination by RDX at the Dundurn site which indicates that soil and groundwater contamination seem curiously not directly related. The minimum detection limit of the HPLC method used is one order of magnitude higher than the selected soil criteria which makes impossible the estimation of the contaminated volume of soil by RDX.

No contamination of soil occured with HMX. HMX concentrations in soil are undetected or are detected at two sites at 0.4 ppm which is far below the proposed 2 2 ppm criteria.

We recommend to the Ministry of defence to make a risk analysis based on health or ecotoxicological data to generate site specific criteria for TNT and RDX in soil and groundwater. From this evaluation it will be decided if a more precise soil analysis method is needed.

The extent of groundwater contamination by RDX and the groundwater flow direction must be better defined before performing a risk analysis. Also, groundwater usage in the area as well aquifer classification should be better known. We propose the drilling of additonnal wells downgradient of the P-3 site. To better understand RDX and TNT circulation and transformation in groundwater we also propose the installation of two succion lysimeters in the vadose zone in the main burning area.

For a better interpretation of the link between TNT in groundwater and soil, we recommend to analyze soil samples (P-3 15-20, 35-40, 45-50; P-6 25-30, 30-35, P-7 15-20) with the more precise HPLC technique.

Additionnal groundwater sampling is required in the shallow well of the P-7 site to verify if cross-contamination by RDX and HMX occured during well installation. If contamination persists, an upgradient well should be installed to verify groundwater flow in this area.

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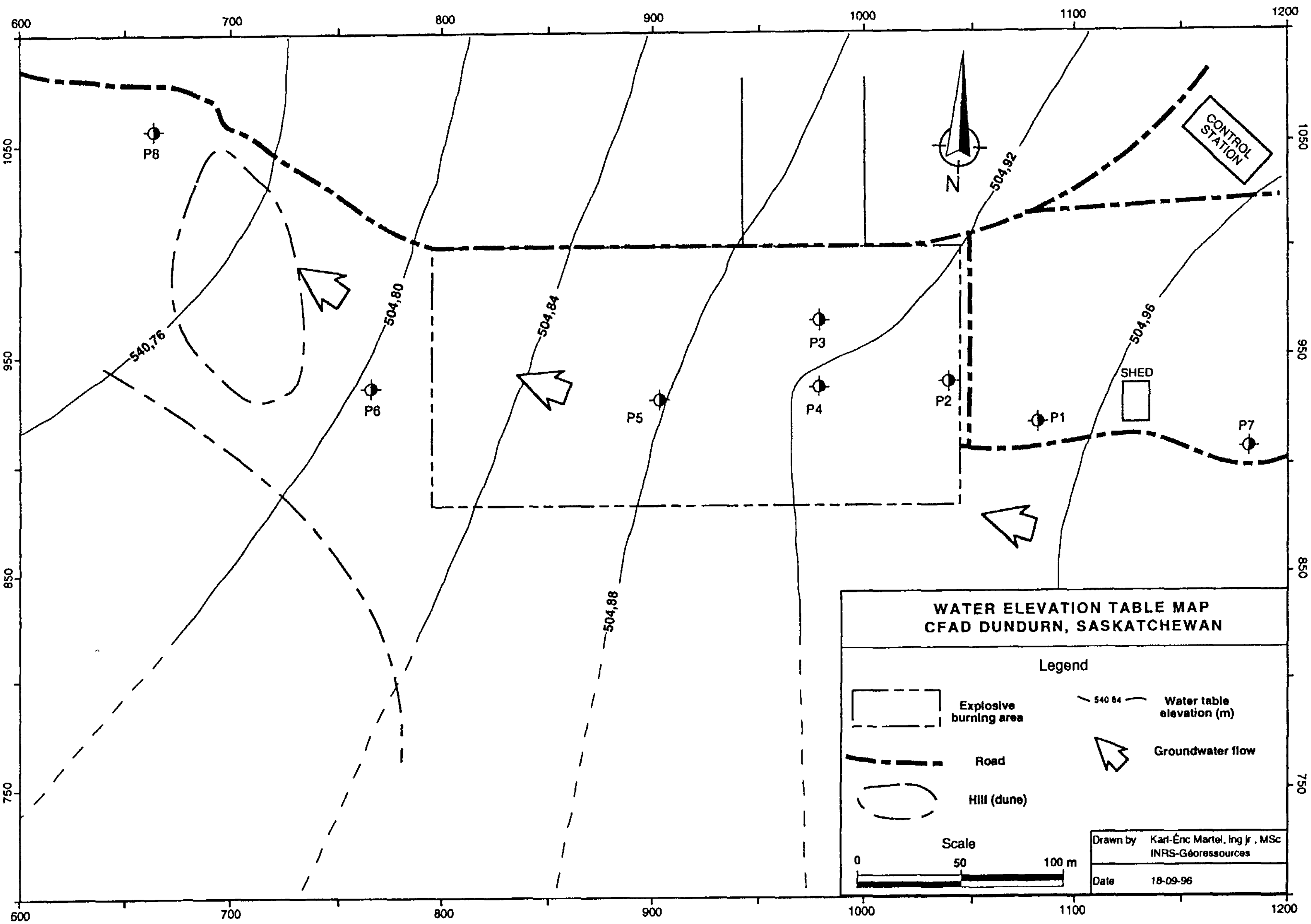


Figure 1. Water table elevation map and groundwater flow.

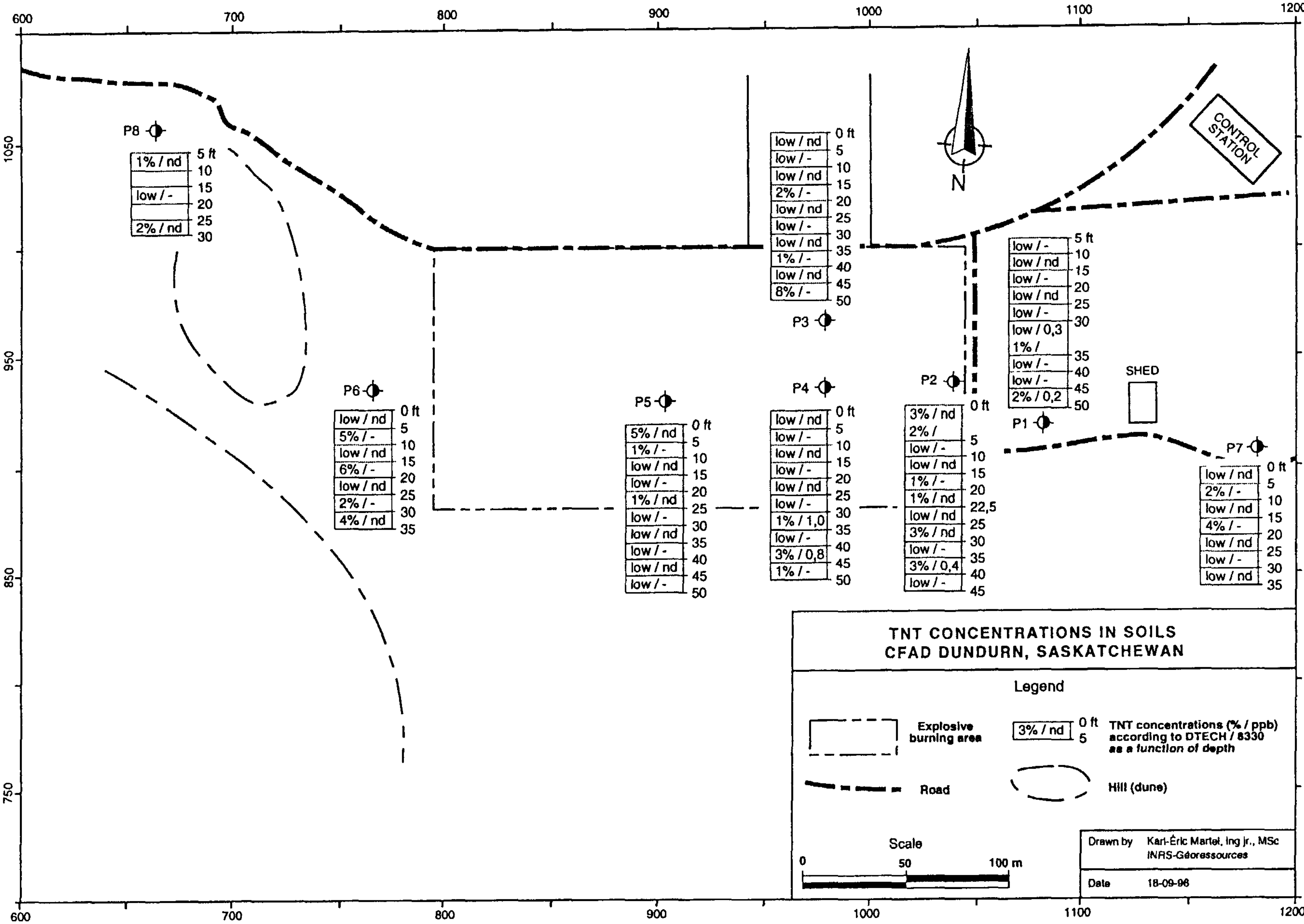


Figure 2. TNT concentrations in soil samples.

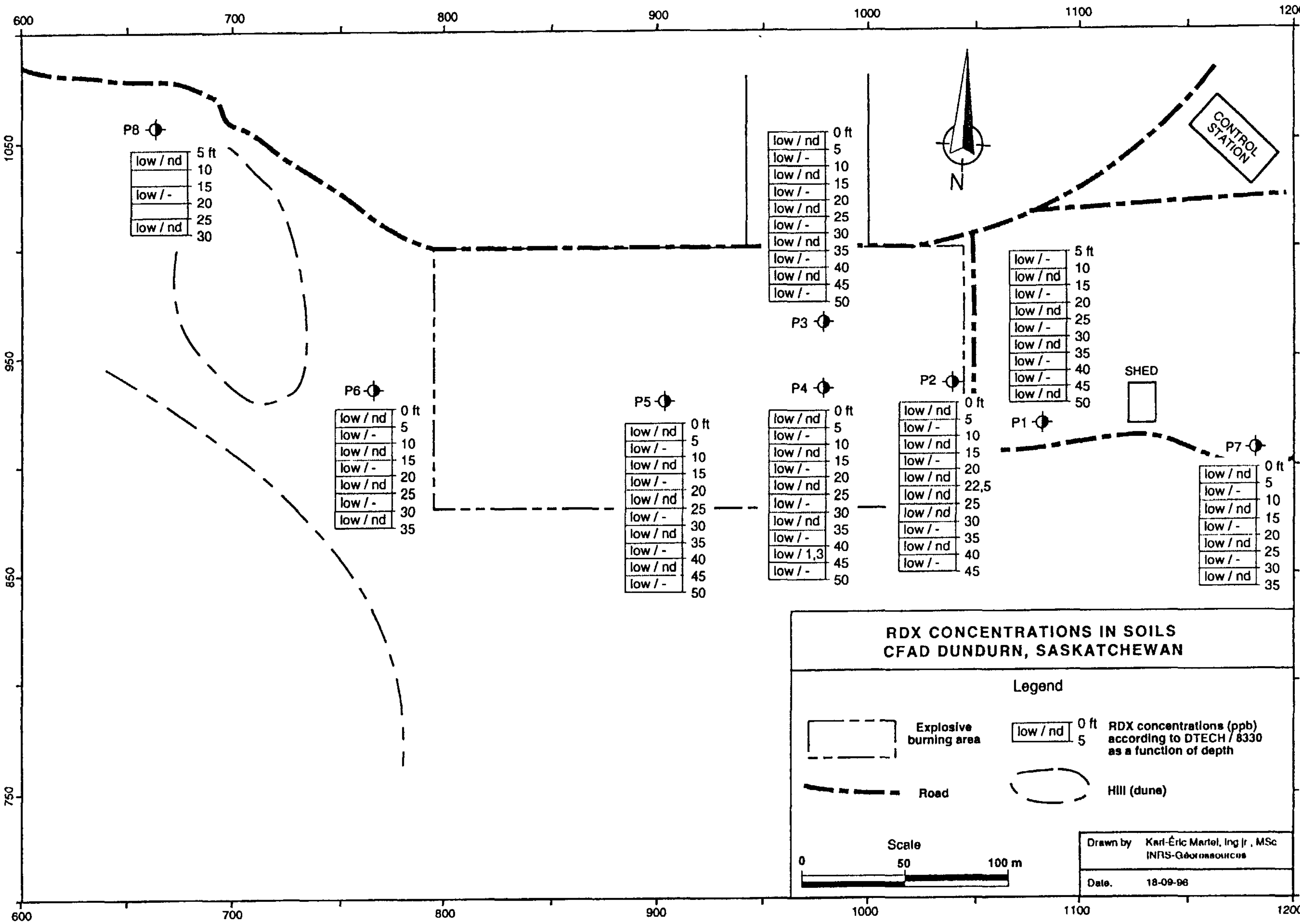


Figure 3. RDX concentrations in soil samples.

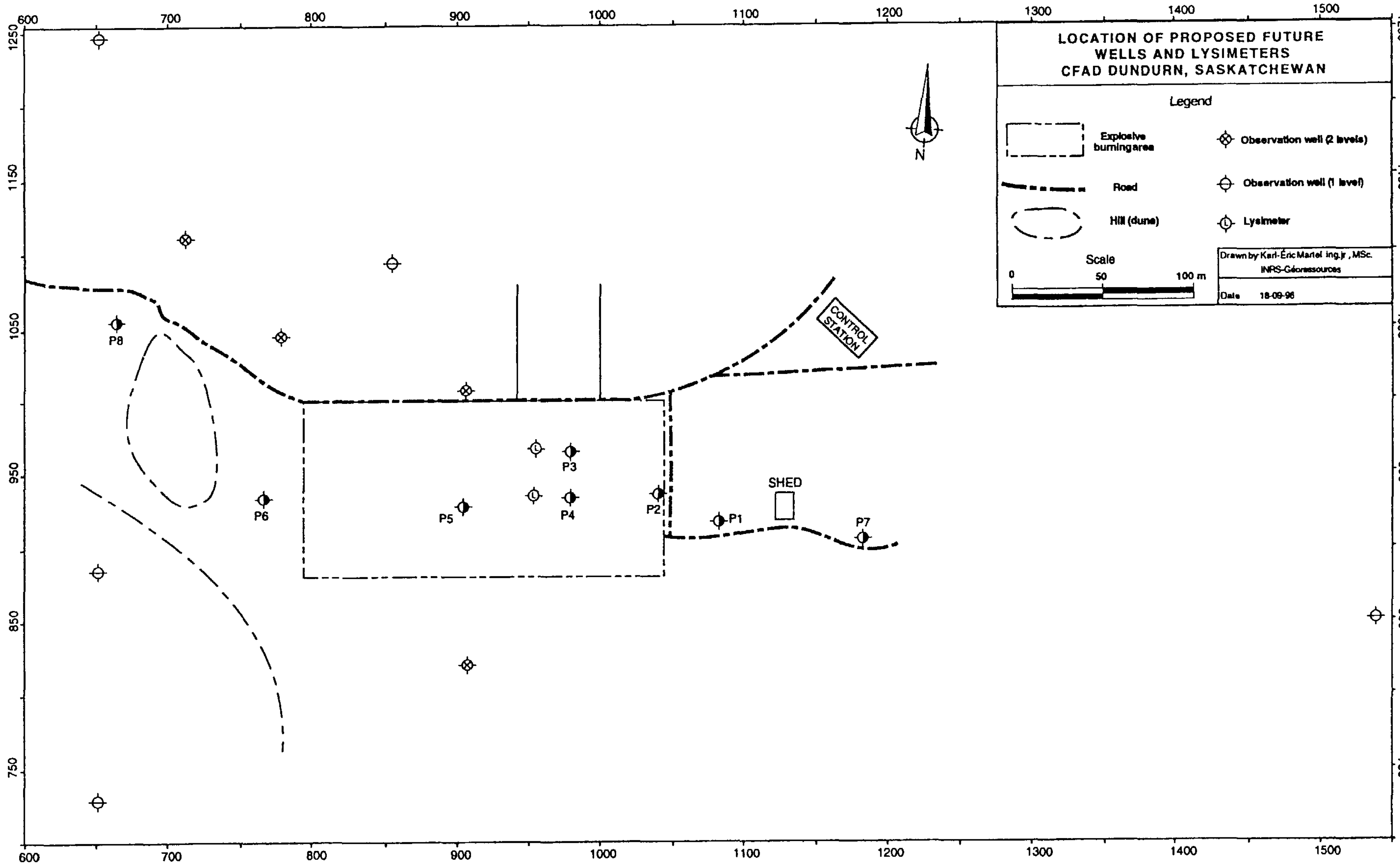


Figure 4. Location of proposed future wells and lysimeters.

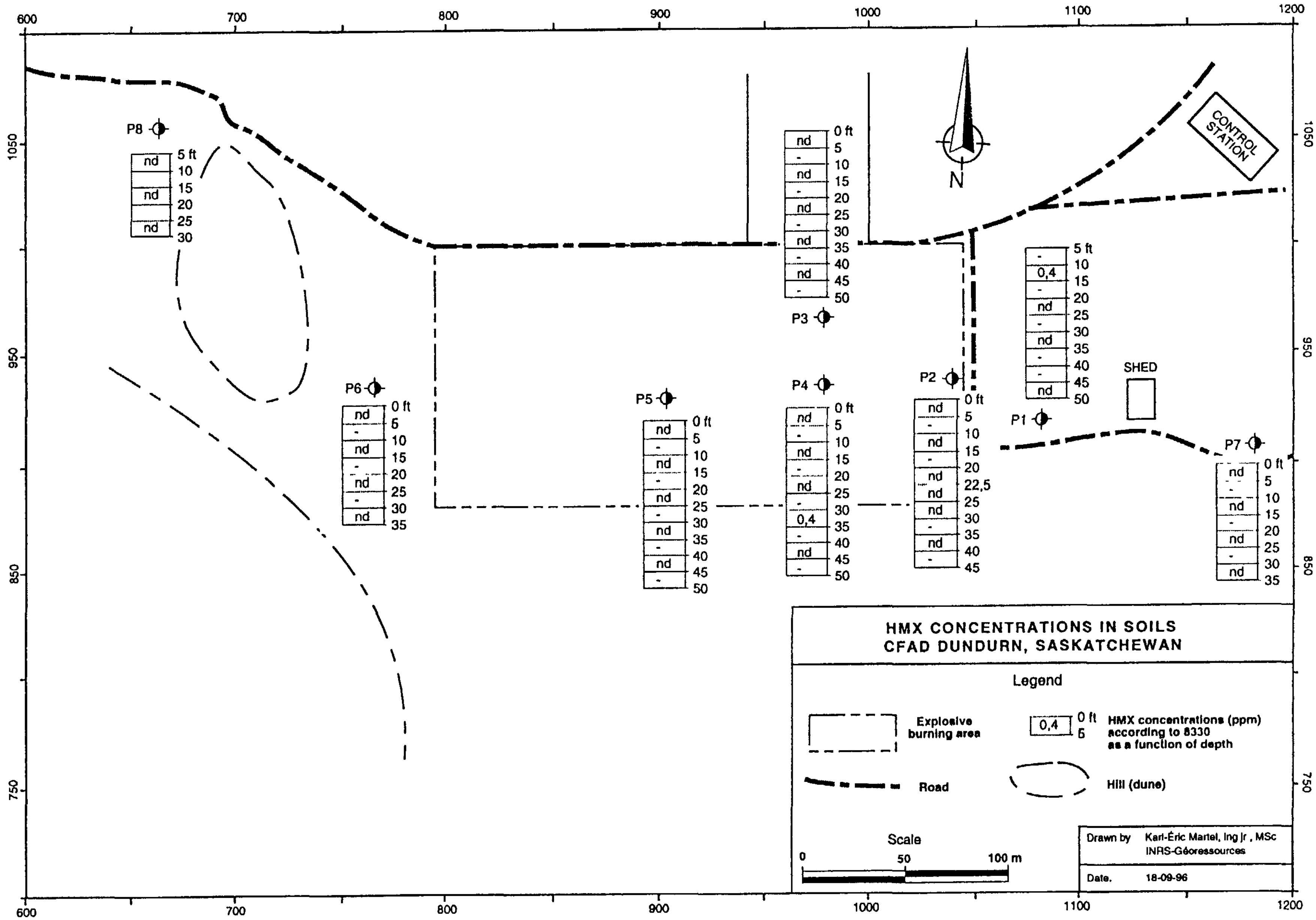


Figure 5. HMX concentrations in soil samples.

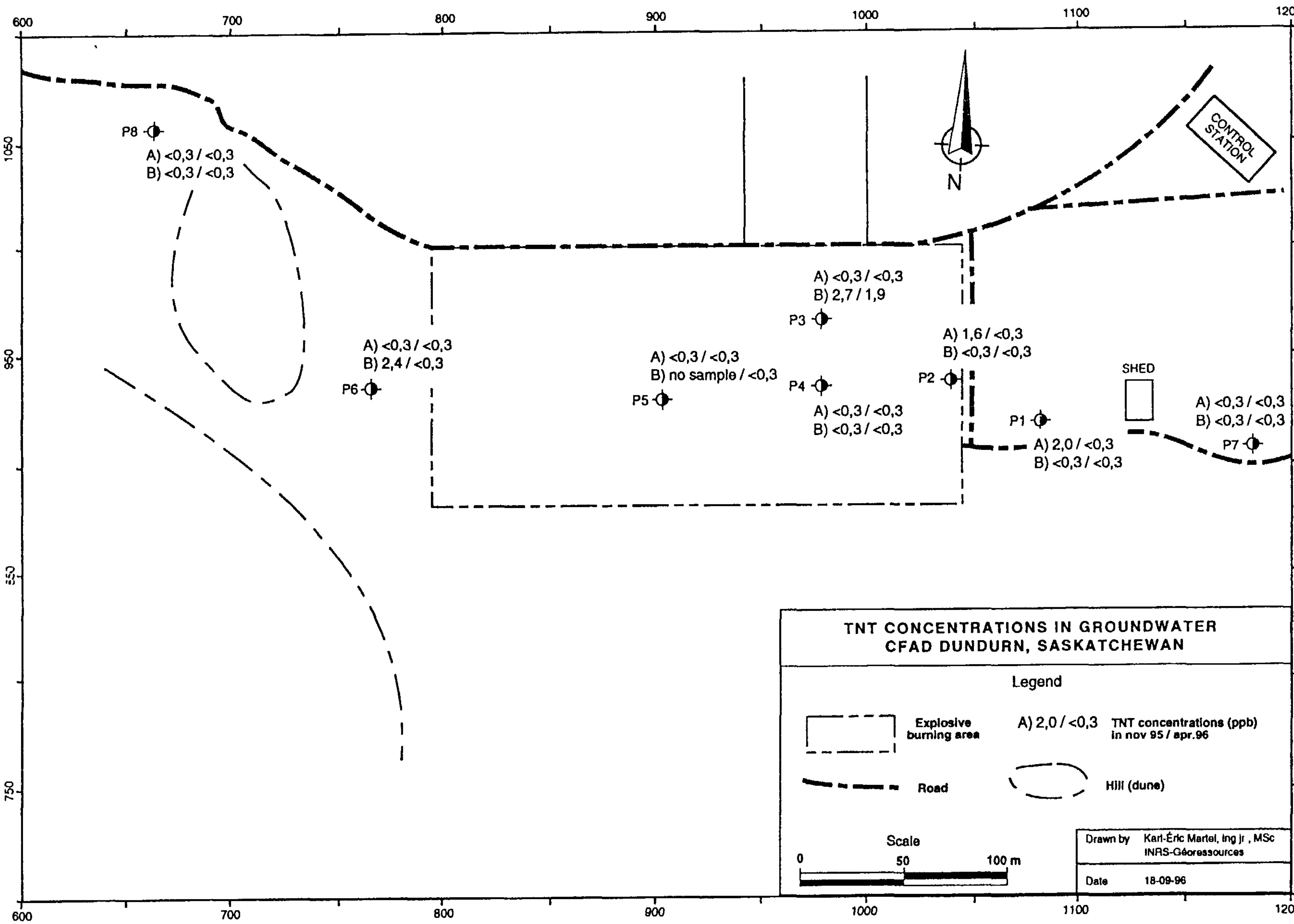


Figure 6. TNT concentrations in groundwater samples.

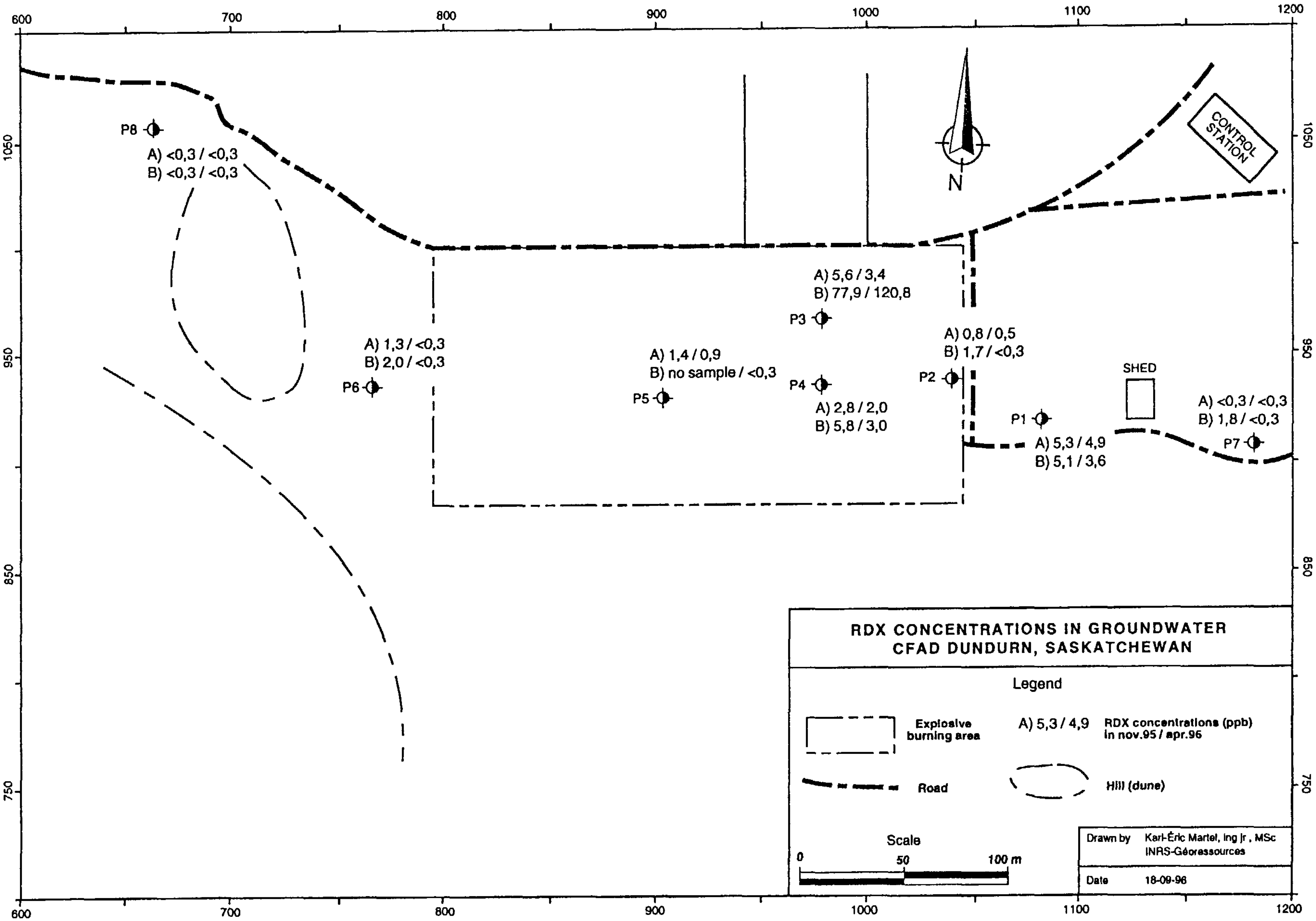


Figure 7. RDX concentrations in groundwater samples.

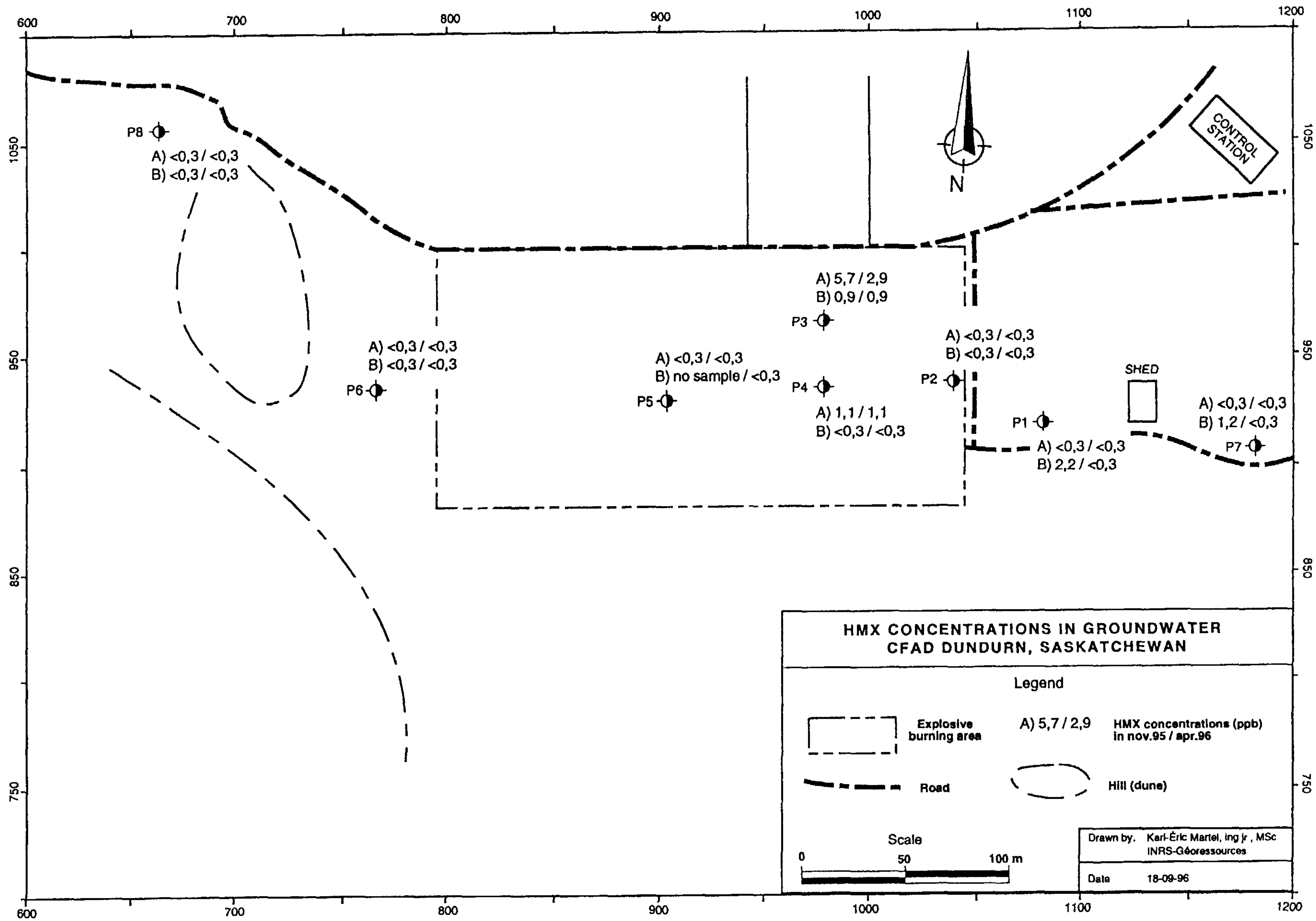
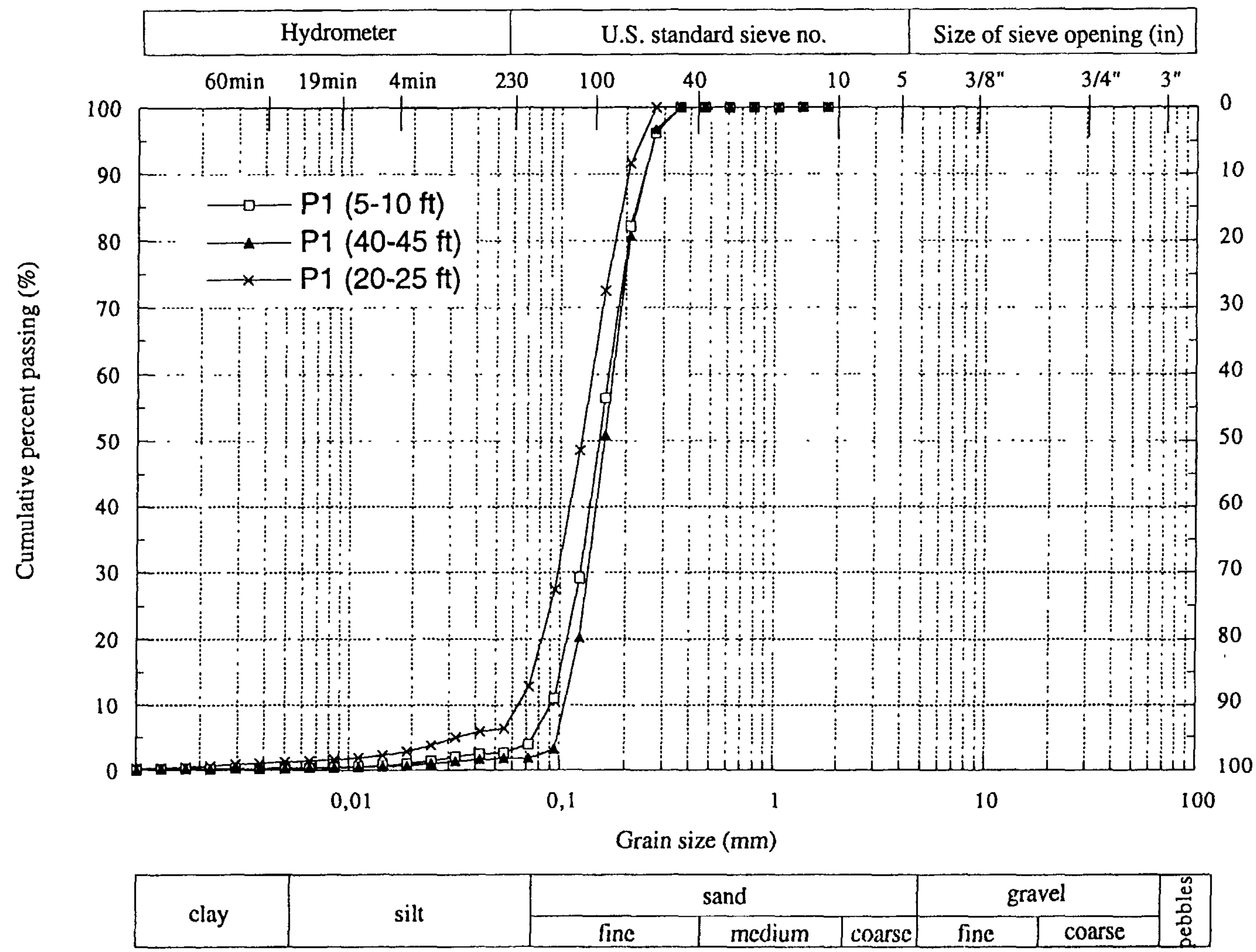


Figure 8. HMX concentrations in groundwater samples.

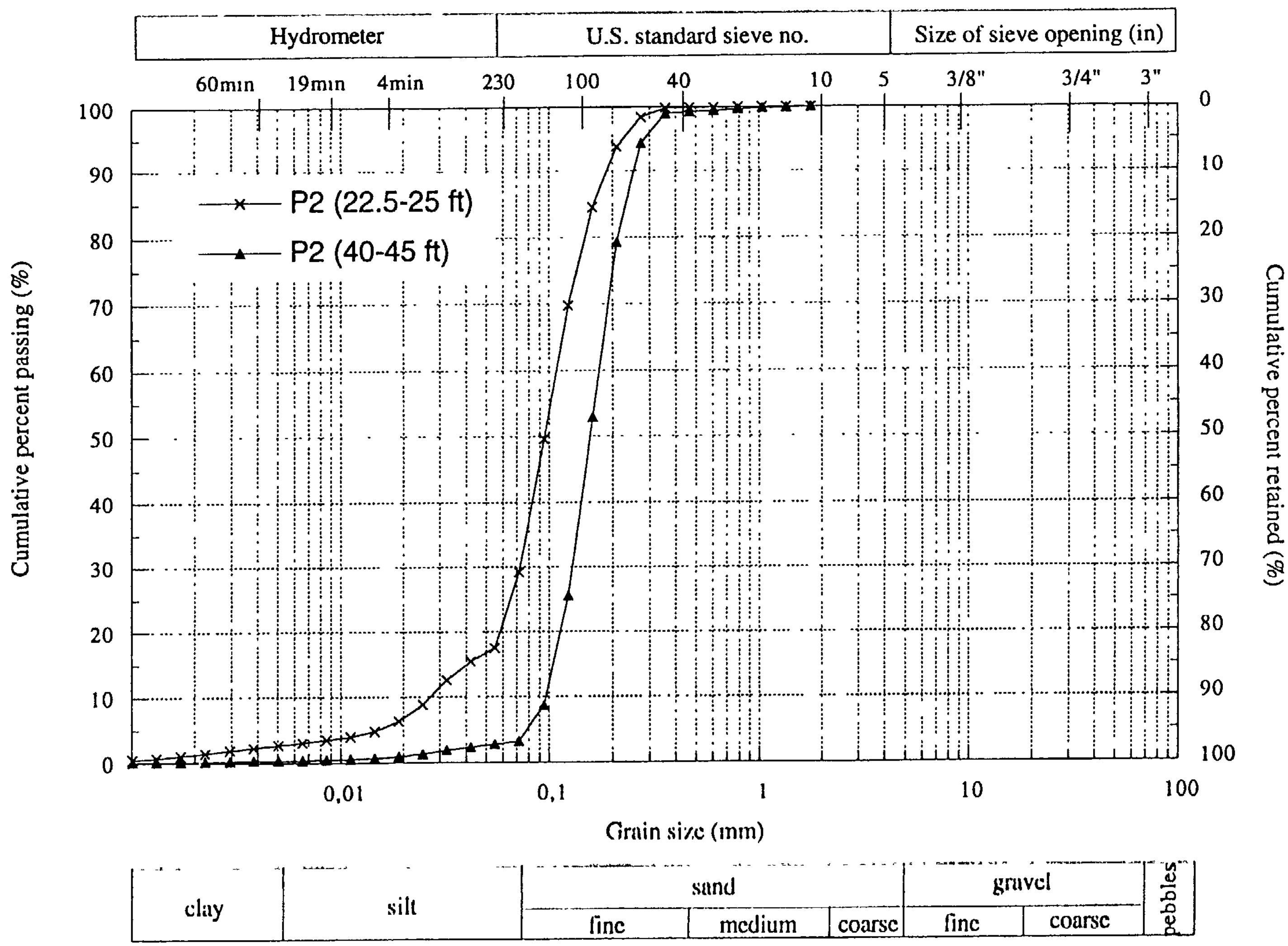
APPENDIX 1.

Grain-size curves

Grain-size distribution curve



Grain-size distribution curve



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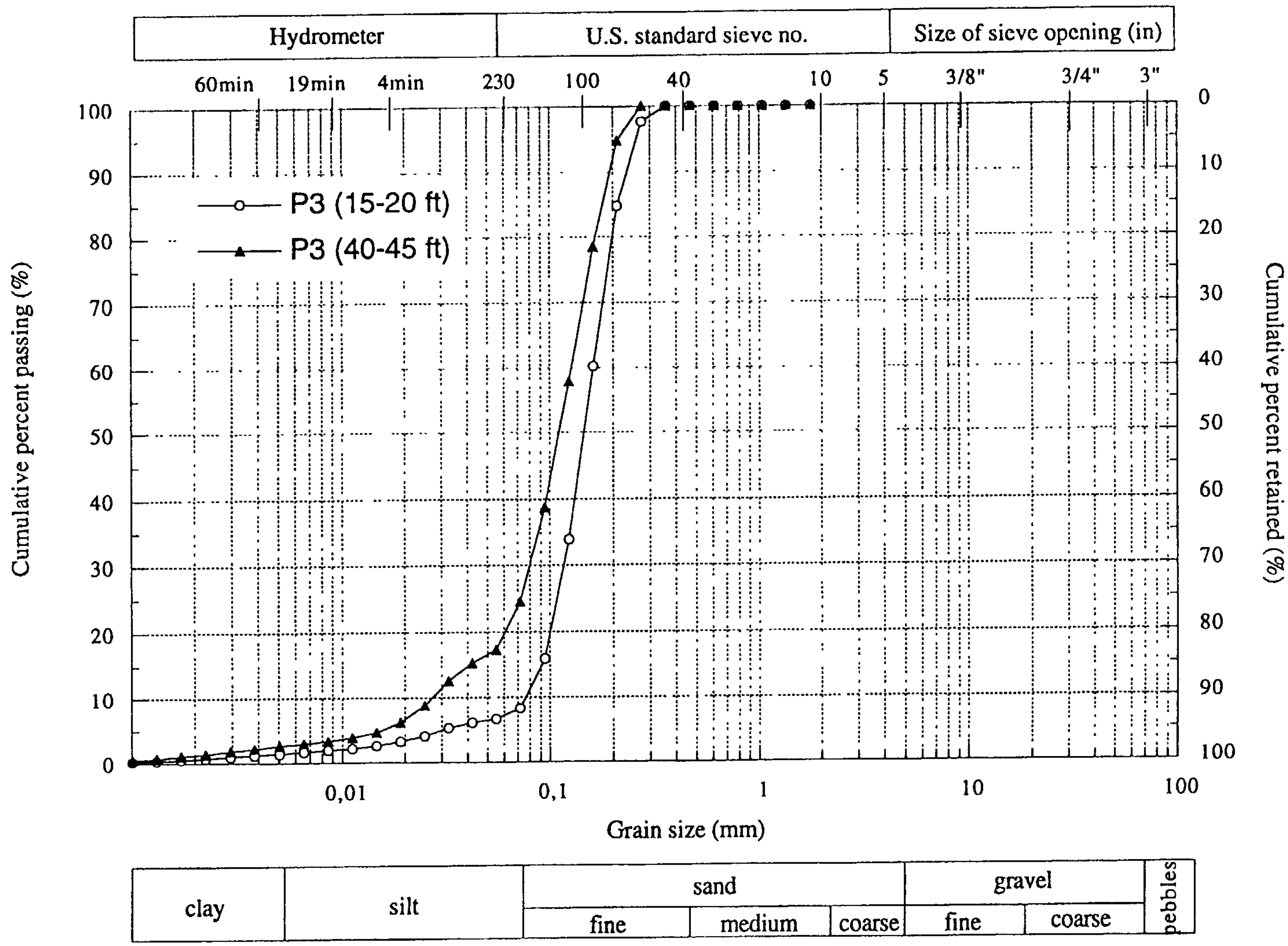
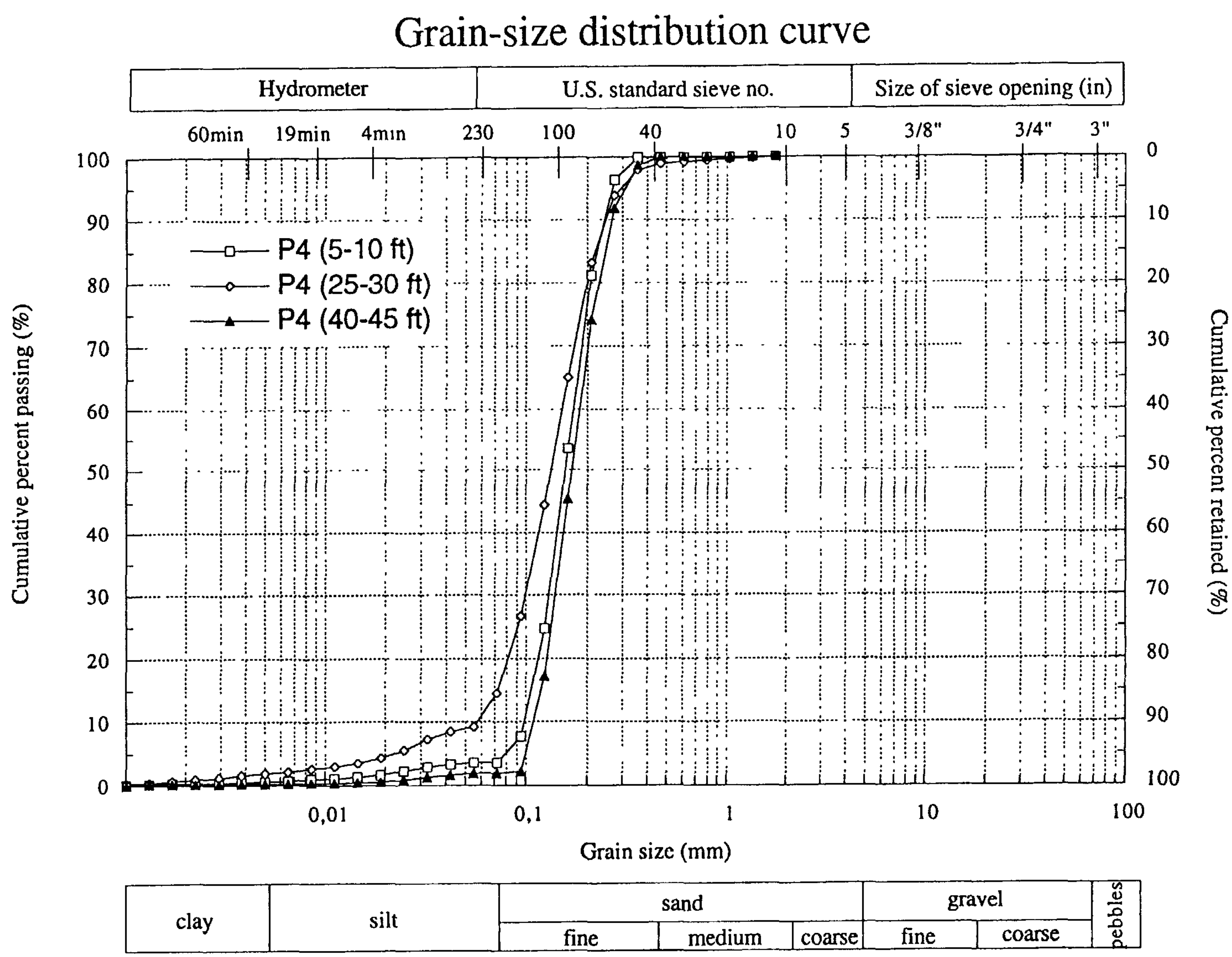
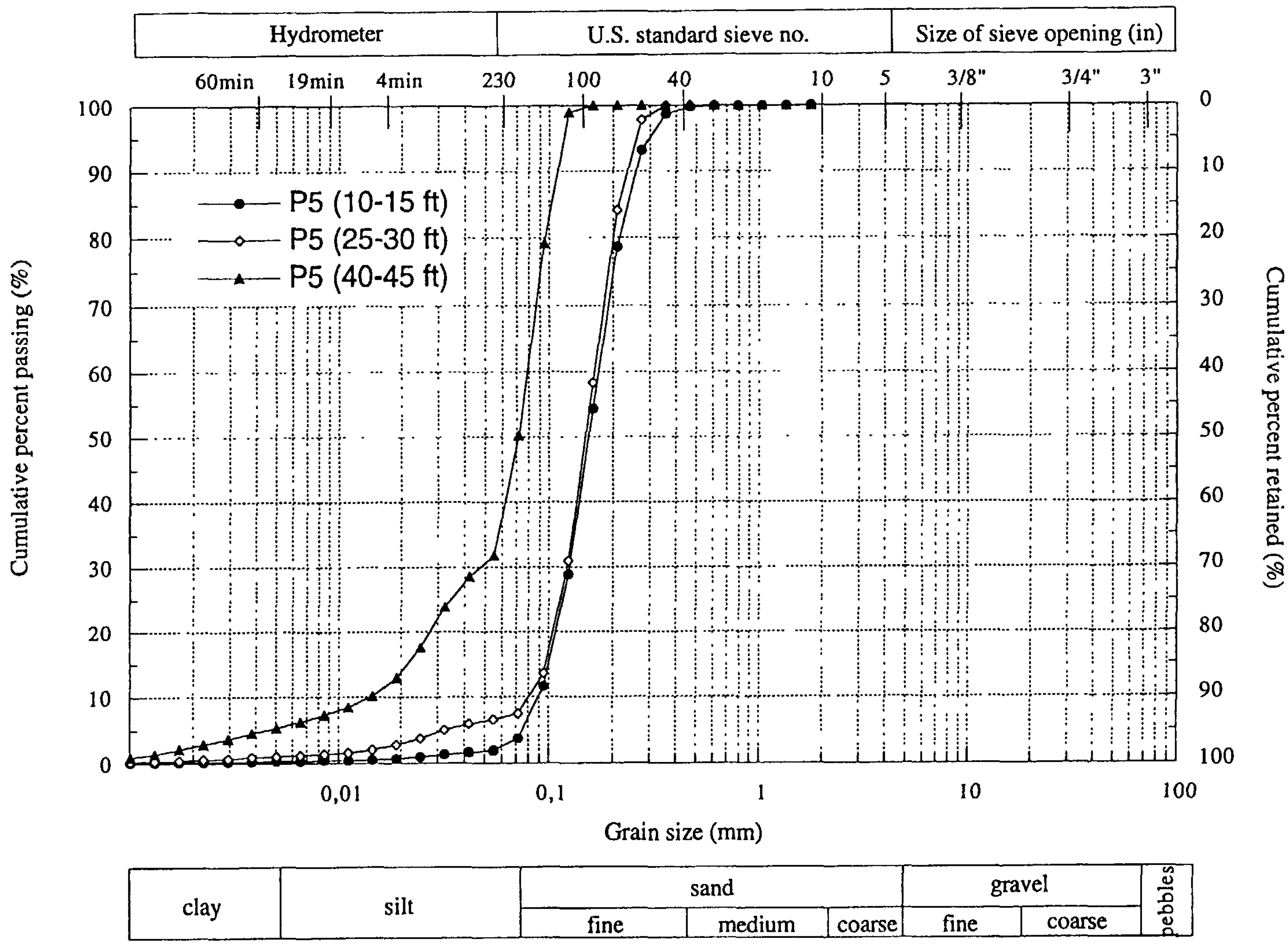


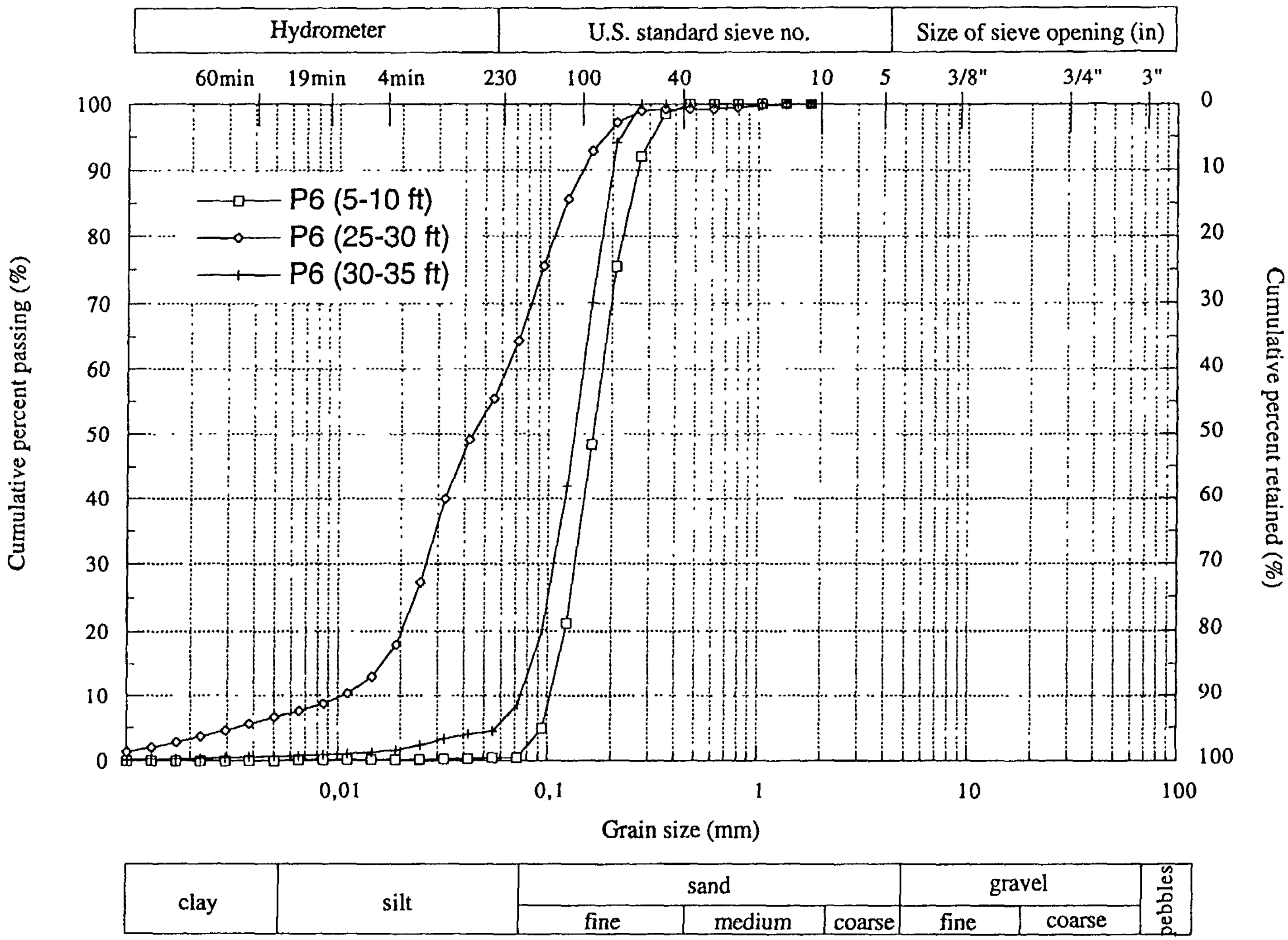


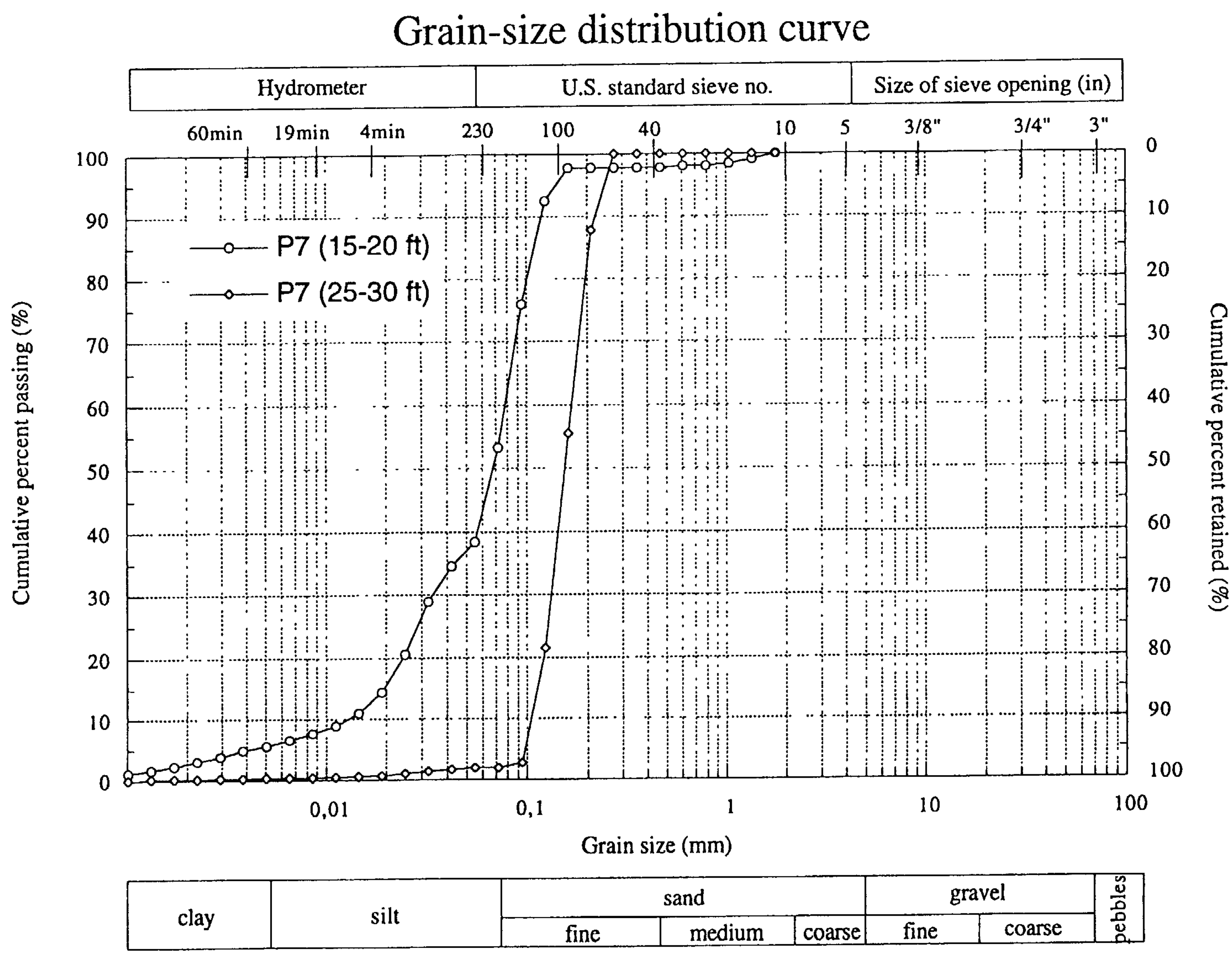
Grain-size distribution curve
Hydrometer
U.S. standard sieve no.
Size of sieve opening (in)
60min
19min
4min
230
100
40
10
5
3/8"
3/4"
3"
P4 (5-10 ft)
P4 (25-30 ft)
P4 (40-45 ft)
Cumulative percent passing (%)
Cumulative percent retained (%)
0,01
0,1
1
10
100
Grain size (mm)
clay
silt
sand
fine
medium
coarse
gravel
fine
coarse
pebbles

Grain-size distribution curve



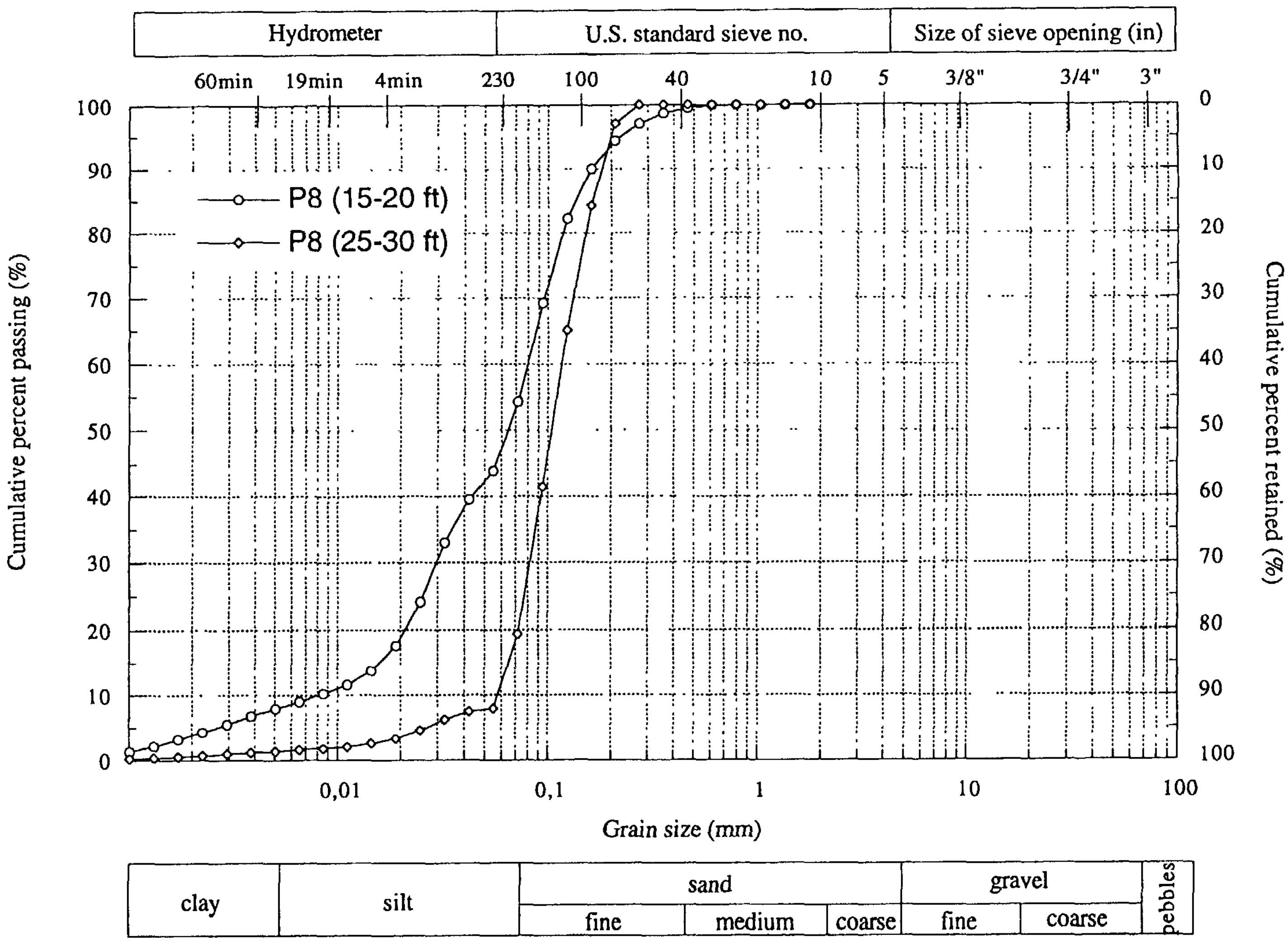
Grain-size distribution curve





Grain-size distribution curve
Hydrometer
U.S. standard sieve no.
Size of sieve opening (in)
60min
19min
4min
230
100
40
10
5
3/8"
3/4"
3"
P7 (15-20 ft)
P7 (25-30 ft)
Cumulative percent passing (%)
Cumulative percent retained (%)
0,01
0,1
1
10
100
Grain size (mm)
clay
silt
sand
fine
medium
coarse
gravel
fine
coarse
pebbles

Grain-size distribution curve



APPENDIX 2.

Slug test data and hydraulic conductivity in wells

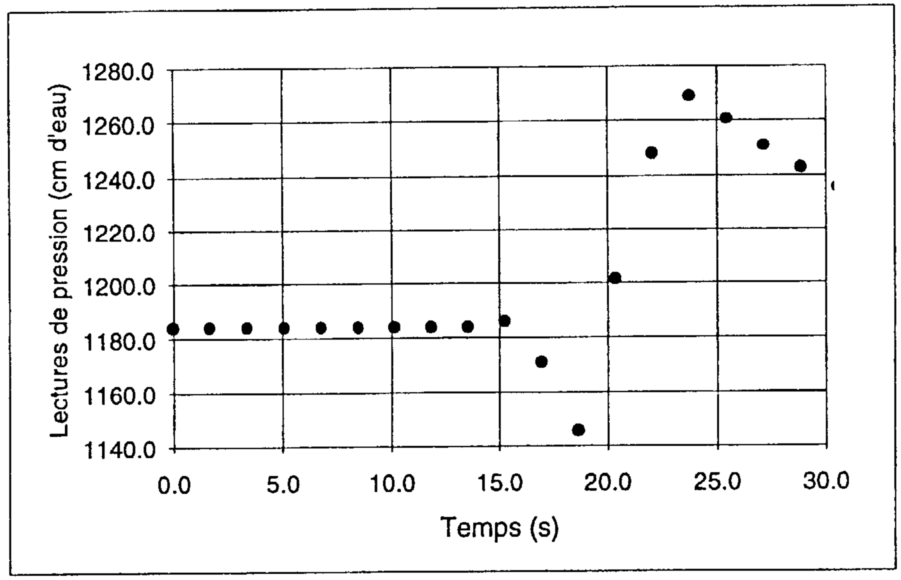
Hydraulic conductivity calculated by slug test in wells

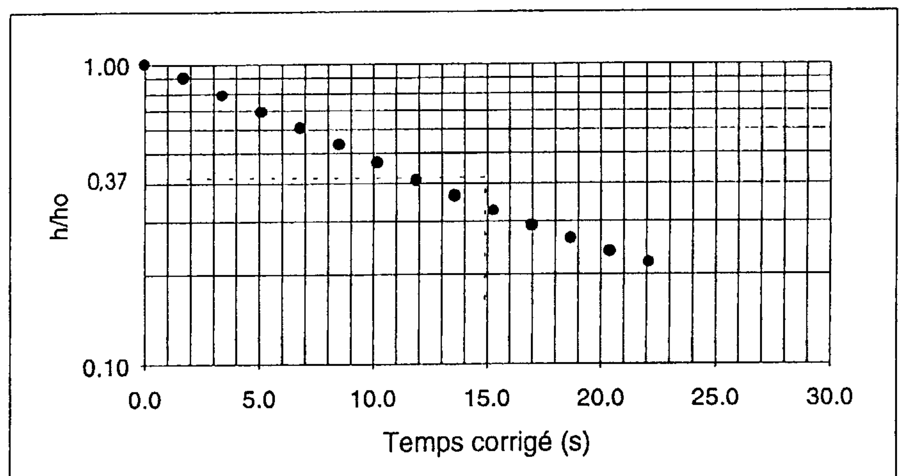
WELL NUMBER	Hydraulic conductivity (m/s)
P-1A	7.7×10^{-5}
P-2A	6.2×10^{-5}
P-3A	1.7×10^{-5}
P-4A	8.1×10^{-5}
P-4B	9.7×10^{-5}
P-5A	2.6×10^{-6}
P-5B	7.5×10^{-5}
P-6A	1.5×10^{-4}
P-6B	4.9×10^{-5}
P-7A	1.0×10^{-4}
P-8A	7.1×10^{-5}
P-8B	$5\ 5 \times 10^{-5}$
Mean hydraulic conductivity	5.0×10^{-5}

Temps (s)	Pression (cm d'eau)	h (cm)	Temps corr. (s)	h/ho
0.0	1183.6	-0.10	-23.8	0.00
1.7	1183.7	0.00	-22.1	0.00
3 4	1183.7	0.00	-20.4	0.00
5.1	1183.7	0.00	-18.7	0.00
6.8	1183.7	0 00	-17 0	0.00
8.5	1183.8	0.10	-15.3	0.00
10.2	1183.8	0.10	-13.6	0.00
11.9	1183 8	0 10	-11 9	0.00
13.6	1183.7	0.00	-10.2	0.00
		Injection d'eau		
15.3	1185.6	1.90	-8.5	0.02
17.0	1170.7	-13.00	-6.8	-0.15
18.7	1145.5	-38 20	-5.1	-0.45
20.4	1201.0	17.30	-3.4	0.20
22.1	1247.9	64.20	-1.7	0.75
		Début de l'essai		
23.8	1268 9	85.20	0.0	1.00
25.5	1260.3	76.60	1.7	0.90
27.2	1250.7	67.00	3.4	0.79
28.9	1242.6	58.90	5.1	0.69
30.6	1235.3	51.60	6.8	0.61
32.3	1229.1	45.40	8.5	0.53
34.0	1223.4	39 70	10.2	0.47
35.7	1218.5	34.80	11.9	0.41
37.4	1214.7	31.00	13.6	0.36
39.1	1211.3	27 60	15.3	0 32
40.8	1208.4	24.70	17 0	0.29
42.5	1206.0	22.30	18.7	0.26
44.2	1204 0	20.30	20.4	0.24
45.9	1202.3	18.60	22.1	0.22

Calibration

	ho=	85.2	cm
(Rayon du puits)	r=	2.54	cm
(Long. crépine)	L=	152.4	cm
(Temps à h/ho = 0,37)	To=	14.0	s





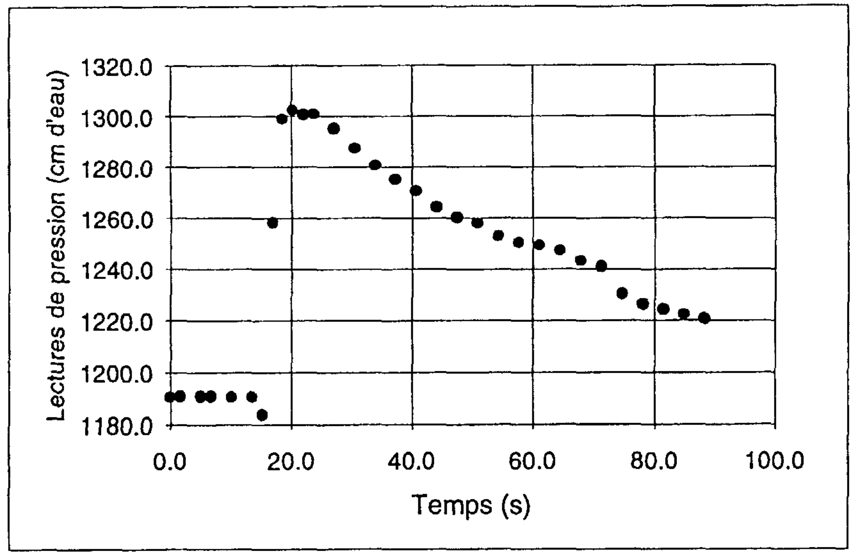
$$K = \frac{r^2 \ \ln (L/r)}{2^*L^*To}$$

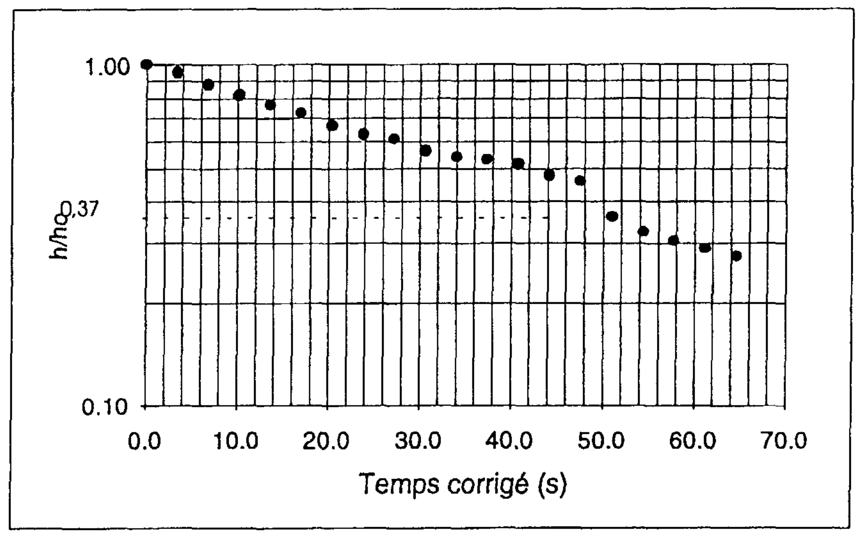
Conductivité hydraulique

K= 6.2E-03 cm/s

Figure 2. Essai de perméabilité à niveau descendant, puits P2a

Temps (s)	Pression (cm d'eau)	h (cm)	Temps corr. (s)	h/ho
		Calibration		
0.0	1190.3	-0.10	-23.8	0.00
1.7	1190.6	0.20	-22.1	0.00
5.1	1190.5	0.10	-18.7	0 00
6.8	1190 5	0.10	-17.0	0.00
10.2	1190.3	-0.10	-13.6	0 00
		Injection d'eau		
13.6	1190.4	0.00	-10 2	0 00
15.3	1183 5	-6.90	-8.5	-0 06
17.0	1258.1	67.70	-6.8	0.61
18.7	1298.8	108.40	-5.1	0.98
20.4	1302.4	112.00	-3.4	1.01
22.1	1300.6	110.20	-1.7	1.00
		Début de l'essai		
23.8	1301.0	110.60	0.0	1.00
27.2	1295.1	104.70	3.4	0.95
30.6	1287.1	96.70	6.8	0.87
34.0	1280.6	90.20	10.2	0 82
37.4	1274.9	84.50	13 6	0 76
40.8	1270.6	80 20	17 0	0.73
44.2	1264.1	73.70	20.4	0.67
47.6	1260.0	69.60	23.8	0.63
51.0	1257.8	67.40	27.2	0.61
54.4	1252.6	62.20	30 6	0.56
57.8	1250.2	59.80	34.0	0.54
61.2	1249.1	58.70	37.4	0.53
64.6	1247.2	56.80	40.8	0.51
68.0	1243.1	52.70	44.2	0.48
71.4	1240.9	50.50	47.6	0.46
74.8	1230.1	39.70	51.0	0.36
78.2	1226.1	35.70	54 4	0.32
81.6	1224.0	33.60	57.8	0.30
85.0	1222.3	31.90	61 2	0.29
88.4	1220.6	30.20	64.6	0.27





	ho=	110.6	cm
(Rayon du puits)	r=	2.54	cm
(Long. crépine)	L=	152.4	cm
(Temps à h/ho = 0,37)	To=	50.5	s

$$K = \frac{r^2 \ln (L/r)}{2 * L * To}$$

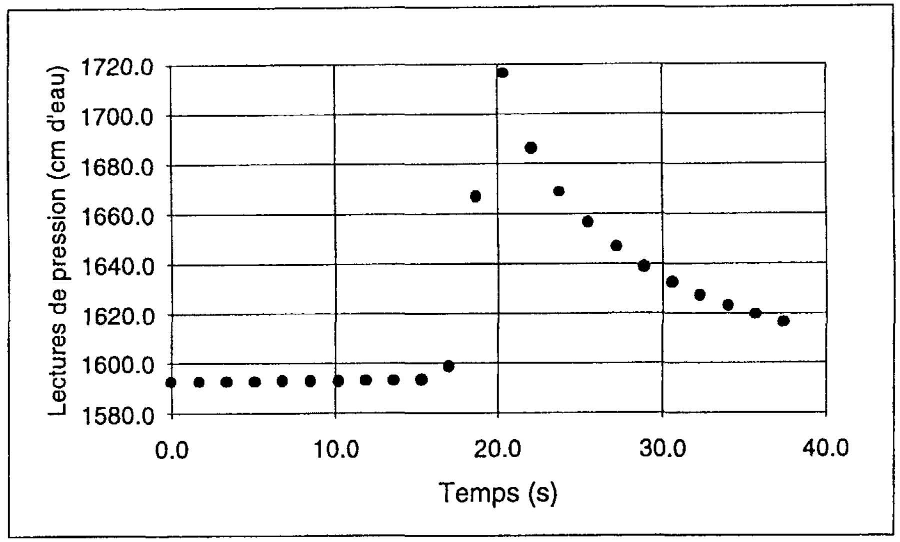
Conductivité hydraulique

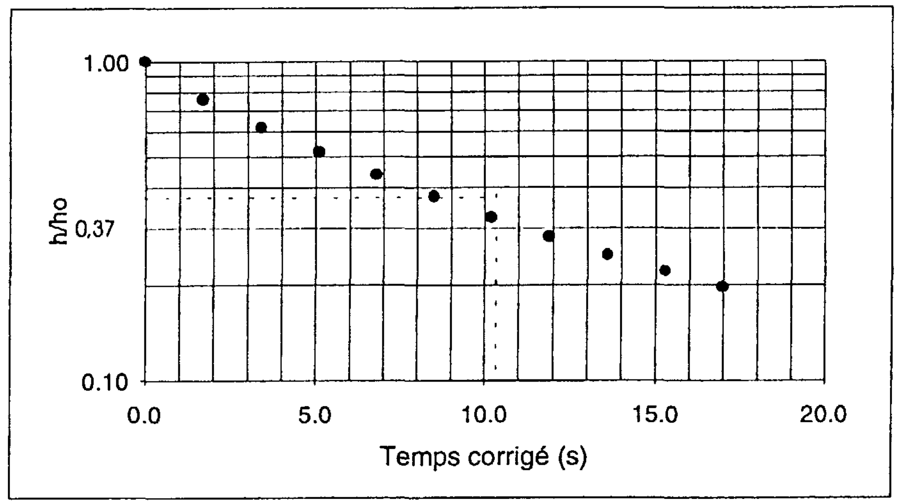
K= 1.7E-03 cm/s

Figure 3. Essai de perméabilité à niveau descendant, puits P3a

Temps	Pression	h	Temps corr.	h/ho
(s)	(cm d'eau)	(cm)	(s)	
		Calibration		
0.0	1592.3	0.00	-20.4	0 00
1.7	1592.3	0.00	-18.7	0.00
3 4	1592.4	0.10	-17.0	0 00
5 1	1592.5	0.20	-15.3	0.00
6.8	1592.6	0.30	-13.6	0 00
8 5	1592.6	0.30	-11.9	0.00
10.2	1592 7	0.40	-10.2	0.00
11.9	1592.8	0.50	-8.5	0 00
13.6	1592.8	0.50	-6.8	0.00
		Injection d'eau		
15.3	1593.1	0 80	-5.1	0.01
17.0	1598 3	6.00	-3.4	0.05
18.7	1666.7	74.40	-1.7	0.60
		Début de l'essai		
20.4	1716.0	123.70	0.0	1 00
22.1	1686.0	93.70	1.7	0.76
23.8	1668.5	76.20	3.4	0 62
25.5	1656.2	63 90	5.1	0 52
27.2	1646.6	54.30	6 8	0.44
28.9	1638.7	46.40	8.5	0.38
30.6	1632.3	40.00	10.2	0 32
32.3	1627.1	34.80	11.9	0.28
34.0	1622.8	30.50	13 6	0 25
35.7	1619 4	27.10	15 3	0.22
37.4	1616.5	24.20	17 0	0.20

	ho=	123.7	cm
(Rayon du puits)	r=	2.54	cm
(Long. crépine)	L=	152.4	cm
(Temps à h/ho = 0,37)	To=	10.7	s





$$K = \frac{r^2 \ \ln (L/r)}{2*L*To}$$

Conductivité hydraulique

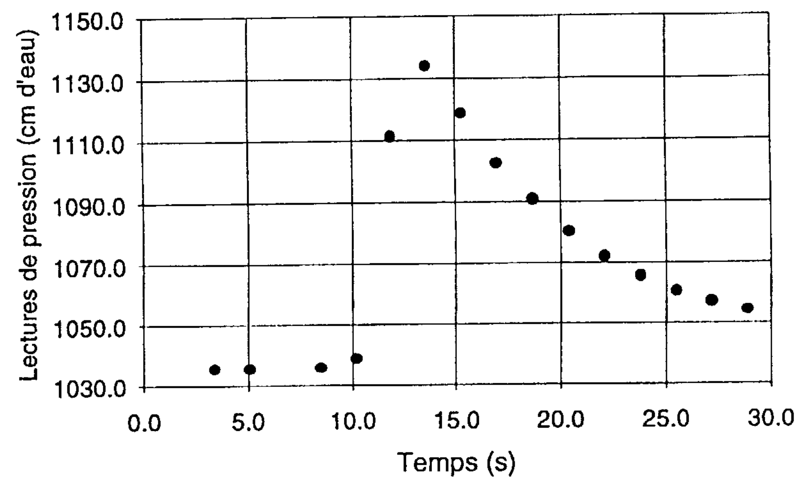
K= 8.1E-03 cm/s

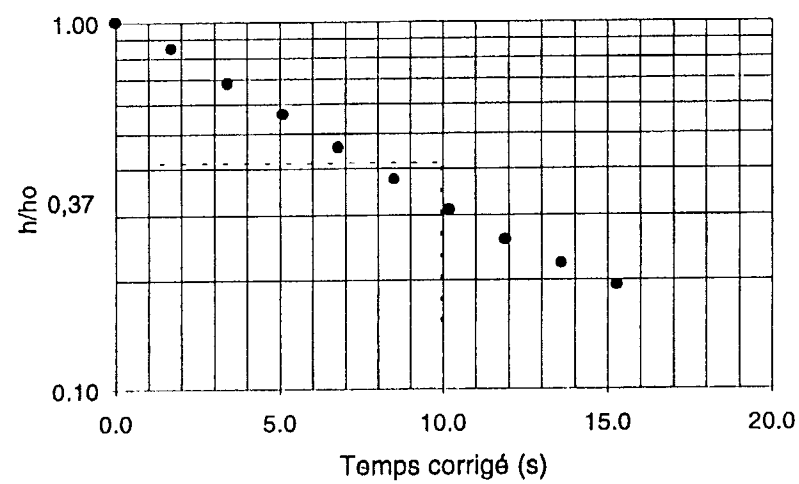
Figure 4. Essai de perméabilité à niveau descendant, puits P4a

Temps (s)	Pression (cm d'eau)	h (cm)	Temps corr. (s)	h/ho
0.0	1035 3	-98.40	-13.6	-1 00
3 4	1035.3	-98.40	-10.2	-1.00
5.1	1035.3	-98 40	-8.5	-1.00
8 5	1035 6	-98.10	-5.1	-1.00
	Injection d'eau			
10.2	1038.7	-95.00	-3.4	-0 97
11 9	1111.1	-22.60	-1.7	-0.23
	Début de l'essai			
13.6	1133.7	98.40	0.0	1.00
15.3	1118 6	83.30	1.7	0.85
17.0	1102.3	67.00	3.4	0.68
18.7	1090.6	55.30	5.1	0.56
20.4	1080 2	44.90	6.8	0.46
22.1	1072.0	36.70	8.5	0.37
23.8	1065.6	30.30	10.2	0.31
25.5	1060.5	25.20	11.9	0.26
27.2	1057.1	21 80	13.6	0.22
28.9	1054.3	19.00	15.3	0.19

Calibration

	ho=	98.4	cm
(Rayon du puits)	r=	2.54	cm
(Long. crépine)	L=	152.4	cm
(Temps à h/ho = 0,37)	To=	9.0	s





$$K = \frac{r^2 \ \ln (L/r)}{2*L*To}$$

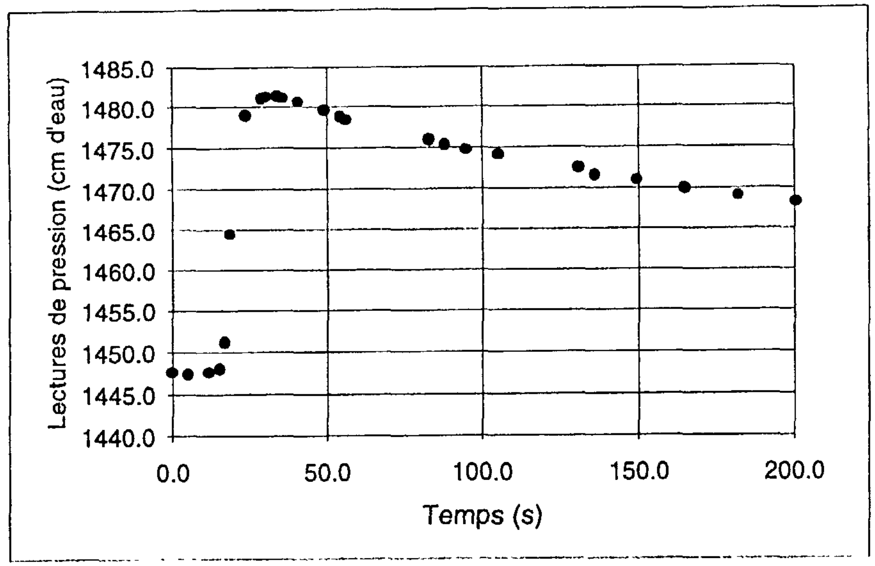
Conductivité hydraulique

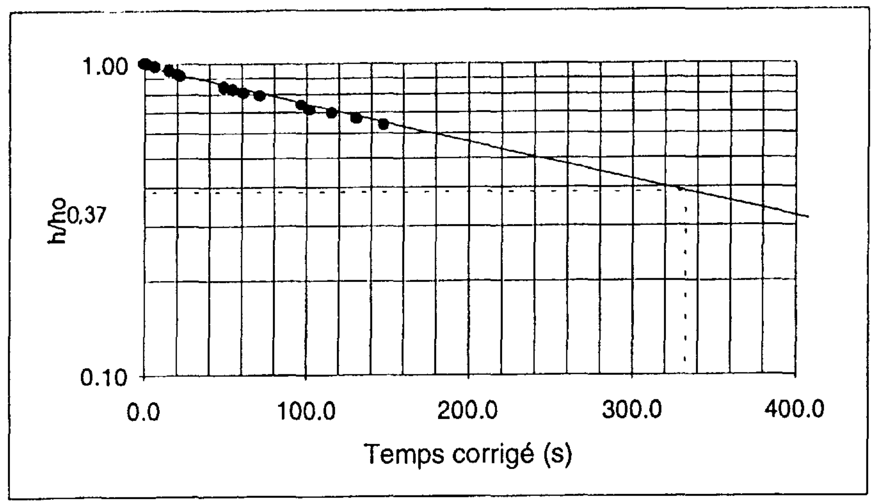
K= 9.7E-03 cm/s

Figure 5. Essai de perméabilité à niveau descendant, puits P4b

Temps	Pression	h	Temps corr.	h/ho
(s)	(cm d'eau)	(cm)	(s)	
0.0	1447.5	0.00	-34.0	0.00
5 1	1447.3	-0.20	-28.9	-0.01
11 9	1447 5	0 00	-22.1	0.00
	Injection d'eau			
15.3	1447.9	0.40	-18.7	0 01
17.0	1451.1	3.60	-17.0	0.11
18.7	1464.4	16.90	-15.3	0 50
23.8	1478.9	31.40	-10.2	0.93
28.9	1481 0	33 50	-5.1	0.99
30.6	1481.2	33.70	-3.4	1.00
	Début de l'essai			
34.0	1481.3	33.80	0.0	1.00
35.7	1481.1	33.60	1.7	0.99
40.8	1480.6	33.10	6.8	0.98
49.3	1479.6	32.10	15.3	0 95
54.4	1478.8	31.30	20.4	0 93
56.1	1478.4	30.90	22.1	0.91
83.3	1475.9	28.40	49.3	0.84
88.4	1475.3	27.80	54.4	0.82
95.2	1474.7	27 20	61.2	0.80
105.4	1474 1	26.60	71.4	0.79
130.9	1472.4	24 90	96.9	0 74
136.0	1471.5	24.00	102.0	0.71
149.6	1470.9	23 40	115.6	0.69
164.9	1469.9	22.40	130.9	0.66
181.9	1469.0	21.50	147.9	0.64
200.6	1468 2	20.70	166.6	0.61

Calibration





	ho=	33.8	cm
(Rayon du puits)	r=	2.5	cm
(Long. crépine)	L=	152.4	cm
(Temps à h/ho = 0,37)	To=	329.6	s

$$K = \frac{r^2 \ \ln (L/r)}{2 {*} L {*} To}$$

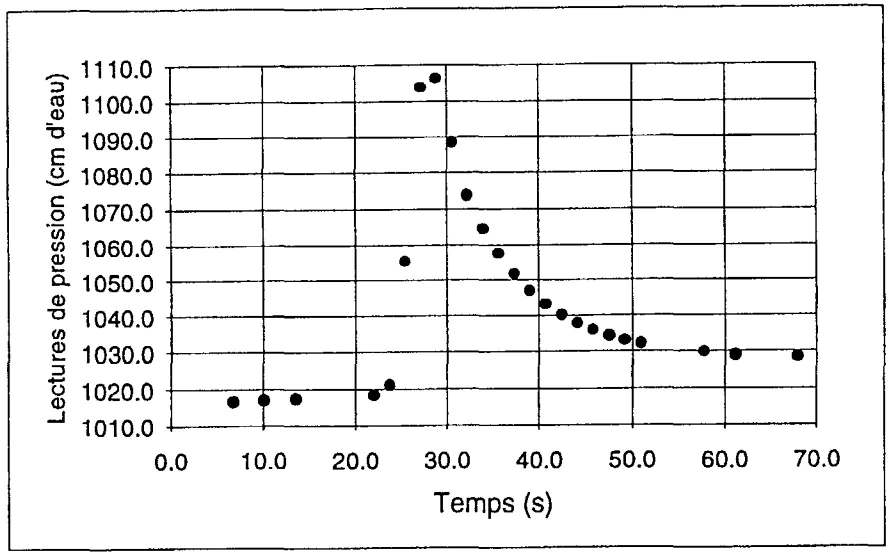
Conductivité hydraulique

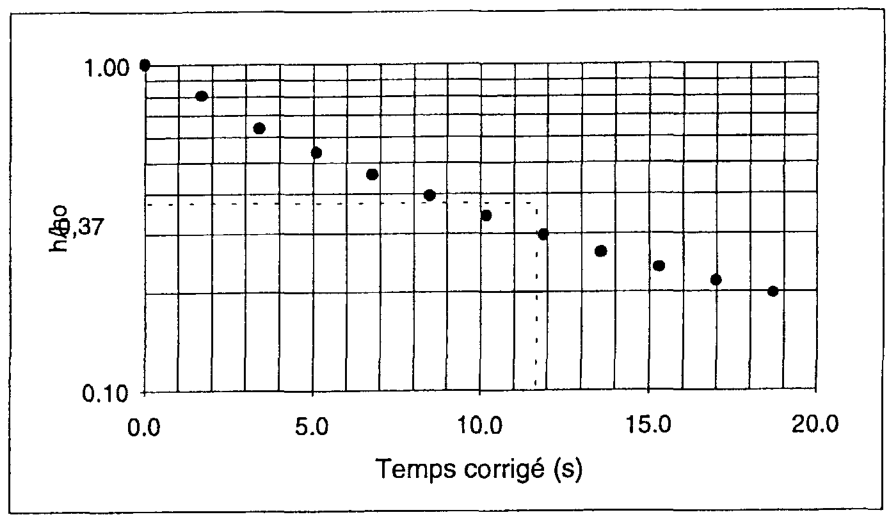
K= 2.6E-04 cm/s

Figure 6. Essai de perméabilité à niveau descendant, puits P5a

Temps (s)	Pression (cm d'eau)	h (cm)	Temps corr. (s)	h/ho	
0.0	1016.1	-0.40	-28.9	0.00	Calibration
6.8	1016.5	0.00	-22.1	0.00	
10.2	1016.9	0.40	-18.7	0.00	
13.6	1017.2	0.70	-15.3	0.01	
	Injection d'eau				
22.1	1018.1	1.60	-6.8	0.02	
23.8	1020.9	4.40	-5.1	0.05	
25.5	1055.3	38.80	-3.4	0.43	
27.2	1103.8	87.30	-1.7	0.97	
	Début de l'essai				
28.9	1106.2	89.70	0.0	1.00	
30.6	1088.5	72.00	1.7	0.80	
32.3	1073.5	57.00	3.4	0.64	
34.0	1064.4	47.90	5.1	0.53	
35.7	1057.5	41.00	6.8	0.46	
37.4	1051.7	35.20	8.5	0.39	
39.1	1046.9	30.40	10.2	0.34	
40.8	1043.0	26.50	11.9	0.30	
42.5	1040.0	23.50	13.6	0.26	
44.2	1037.7	21.20	15.3	0.24	
45.9	1035.8	19.30	17.0	0.22	
47.6	1034.2	17.70	18.7	0.20	
49.3	1033.0	16.50	20.4	0.18	
51.0	1032.0	15.50	22.1	0.17	
57.8	1029.6	13.10	28.9	0.15	
61.2	1028.8	12.30	32.3	0.14	
68.0	1028.2	11.70	39.1	0.13	

	ho=	89.7	cm
(Rayon du puits)	r=	2.54	cm
(Long. crépine)	L=	152.4	cm
(Temps à h/ho = 0,37)	To=	11.609	s





$$K = \frac{r^2 \ln (L/r)}{2^*L^*To}$$

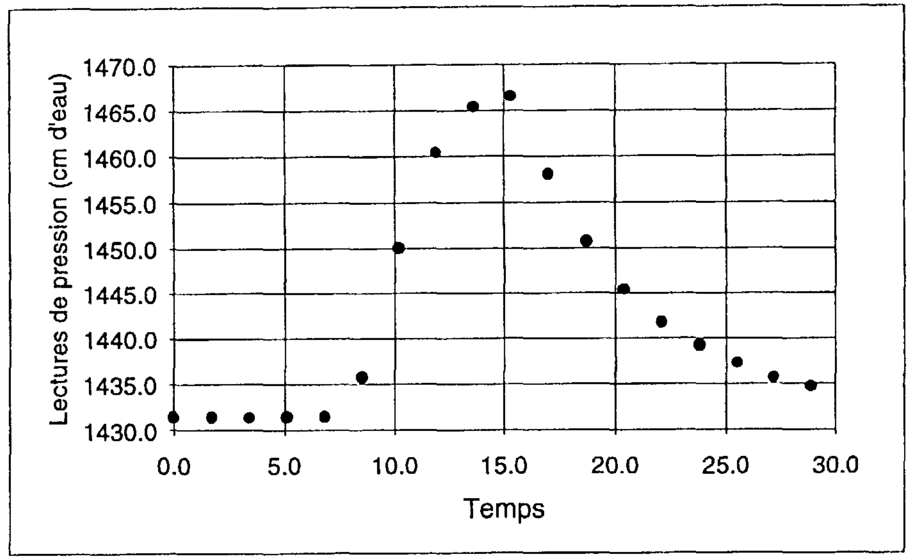
Conductivité hydraulique

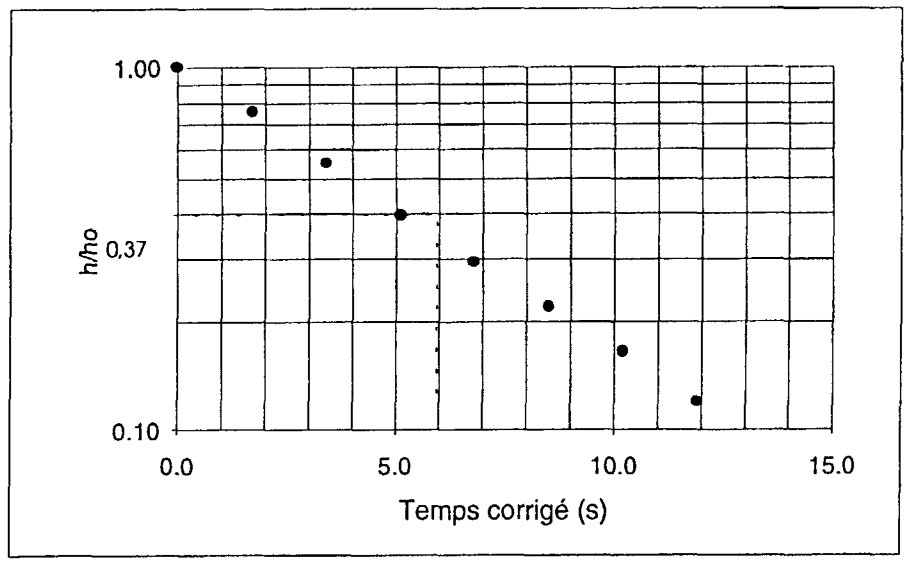
K= 7.5E-03 cm/s

Figure 7. Essai de perméabilité à niveau descendant, puits P5b

Temps	Pression	h	Temps corr.	h/ho	
(s)	(cm d'eau)	(cm)	(s)		
0.0	1431.4	0.00	-15.3	0.00	Calibration
1.7	1431.4	0.00	-13.6	0.00	
3.4	1431 3	-0.10	-11.9	0.00	
5.1	1431.4	0.00	-10.2	0.00	
6.8	1431.4	0 00	-8.5	0.00	
	Injection d'eau				
8.5	1435.7	4.30	-6.8	0.12	
10 2	1450.0	18.60	-5.1	0.53	
11.9	1460.3	28.90	-3.4	0.82	
13.6	1465.3	33.90	-1.7	0 97	
	Début de l'essai				
15.3	1466.5	35 10	0.0	1.00	
17.0	1458 0	26.60	1.7	0.76	
18.7	1450.7	19.30	3.4	0.55	
20.4	1445.3	13.90	5.1	0 40	
22.1	1441.7	10.30	6.8	0.29	
23.8	1439.1	7 70	8.5	0.22	
25.5	1437.2	5.80	10.2	0.17	
27.2	1435.6	4.20	11.9	0.12	
28 9	1434.6	3.20	13.6	0.09	

	ho=	35.1	cm
(Rayon du puits)	r=	2.54	cm
(Long. crépine)	L=	152.4	cm
(Temps à h/ho = 0,37)	To=	5.6	s





$$K = \frac{r^2 \ln(L/r)}{2 * L * To}$$

Conductivité hydraulique

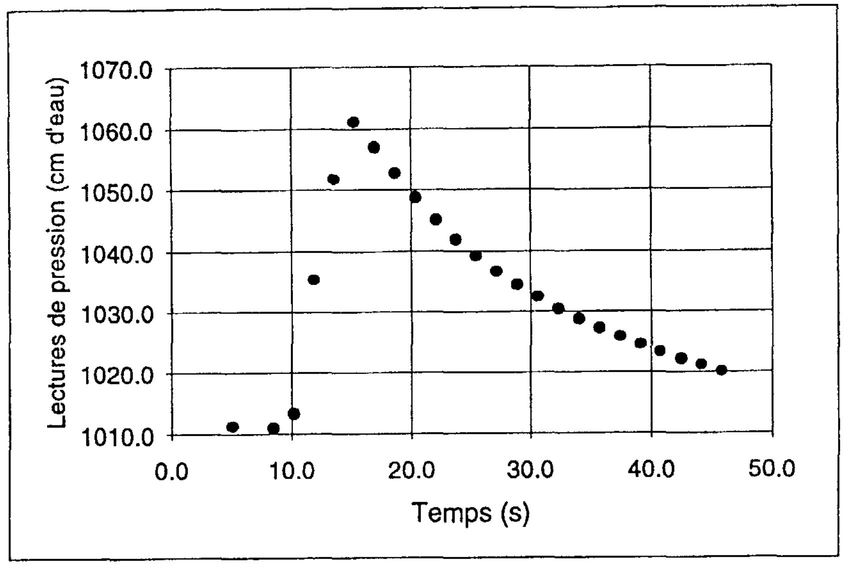
K= 1.5E-02 cm/s

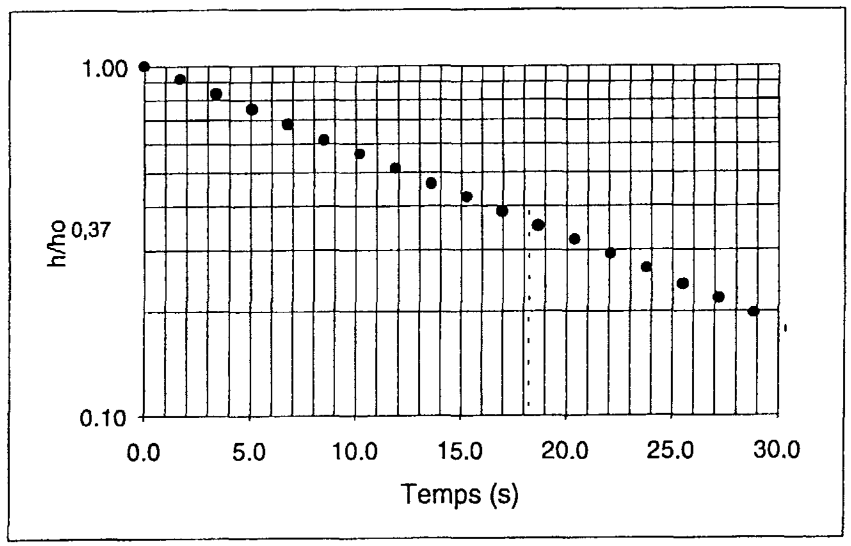
Figure 8. Essai de perméabilité à niveau descendant, puits P6a

Temps (s)	Pression (cm d'eau)	h (cm)	Temps corr. (s)	h/ho
0.0	1012.1	-39.60	-15.3	-0.79
5.1	1011.2	-40.50	-10.2	-0.81
8.5	1010.9	-40.80	-6 8	-0.82
	Injection d'eau			
10.2	1013.2	-38.50	-5.1	-0.77
11.9	1035.3	-16.40	-3.4	-0 33
13.6	1051.7	40.50	-1.7	0.81
	Début de l'essai			
15.3	1061.1	49.90	0.0	1.00
17.0	1056.9	45.70	1.7	0.92
18.7	1052.6	41.40	3 4	0.83
20.4	1048.6	37.40	5.1	0.75
22.1	1045.0	33.80	6.8	0.68
23 8	1041.8	30.60	8.5	0.61
25.5	1039.1	27.90	10 2	0.56
27.2	1036 6	25.40	11.9	0 51
28 9	1034.3	23 10	13.6	0.46
30.6	1032.3	21.10	15 3	0 42
32.3	1030.3	19 10	17.0	0.38
34.0	1028 6	17 40	18.7	0.35
35.7	1027.1	15 90	20 4	0.32
37.4	1025.7	14.50	22.1	0.29
39.1	1024.4	13.20	23.8	0.26
40 8	1023 1	11.90	25 5	0.24
42.5	1022.0	10.80	27.2	0.22
44.2	1021.0	9.80	28.9	0.20
45.9	1020.0	8.80	30.6	0 18

Calibration

	ho=	49.9	cm
(Rayon du puits)	r=	2.54	cm
(Long. crépine)	L=	152.4	cm
(Temps à h/ho = 0,37)	To=	17.7	s





$$K = \frac{r^2 \ln (L/r)}{2*L*To}$$

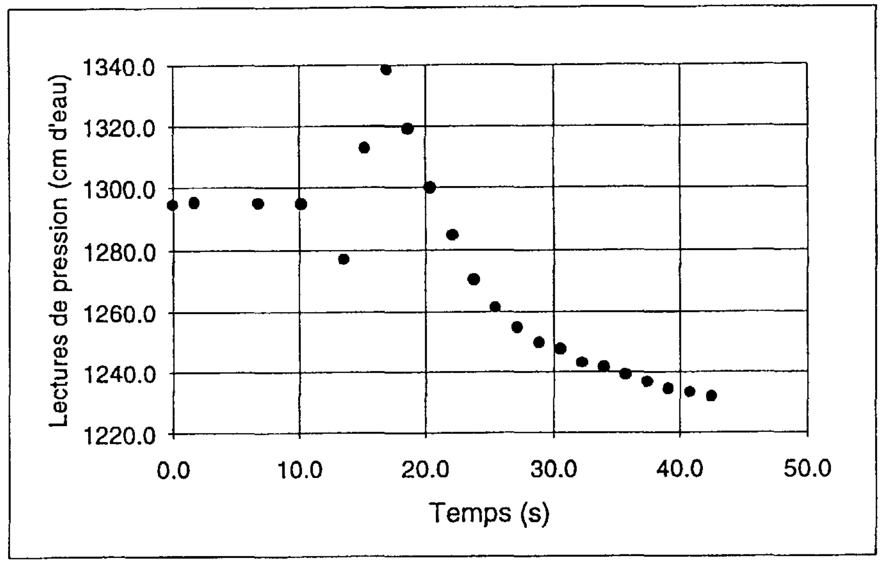
Conductivité hydraulique

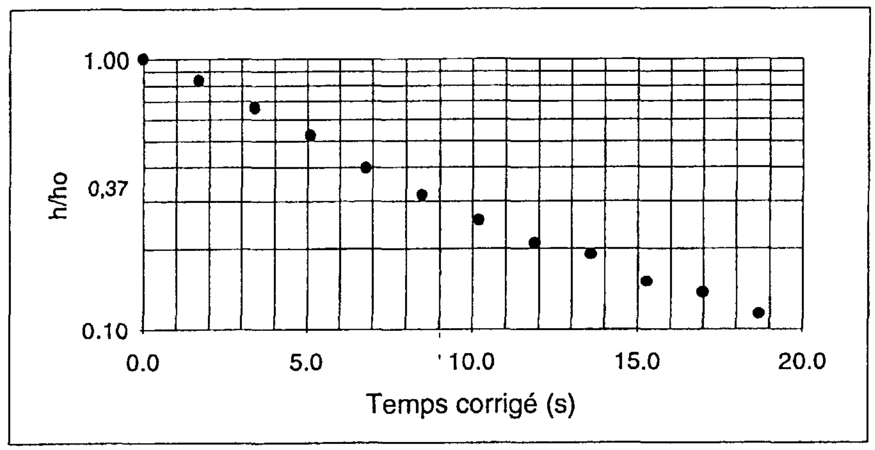
K= 4.9E-03 cm/s

Figure 9. Essai de perméabilité à niveau descendant, puits 6b

Temps	Pression	h	Temps corr.	h/ho	
(s)	(cm d'eau)	(cm)	(s)		
0 0	1294.4	68.40	-23.8	0.61	Calibration
1.7	1295.0	69 00	-22.1	0.61	
6.8	1294.9	68.90	-17.0	0 61	
10 2	1294.6	68.60	-6.8	0.61	
	Injection d'eau				
13.6	1276.9	50.90	-3.4	0.45	
15 3	1312.5	86.50	-1.7	0.77	
	Début de l'essai				
17 0	1338.3	112.30	0.0	1 00	
18.7	1318.9	92.90	1.7	0.83	
20.4	1299.7	73.70	3.4	0.66	
22.1	1284.6	58.60	5.1	0.52	
23 8	1270.4	44.40	6 8	0.40	
25.5	1261.3	35.30	8.5	0.31	
27.2	1254.5	28.50	10.2	0.25	
28.9	1249.5	23.50	11.9	0.21	
30.6	1247.3	21.30	13.6	0.19	
32.3	1242.8	16.80	15.3	0.15	
34.0	1241.3	15.30	17.0	0.14	
35.7	1238.8	12.80	18.7	0.11	
37.4	1236.4	10.40	20 4	0.09	
39.1	1234.2	8.20	22.1	0.07	
40.8	1233.0	7.00	23.8	0.06	
42 5	1231.7	5 70	25.5	0.05	

	ho=	112.3	cm
(Rayon du puits)	r=	2.54	cm
(Long. crépine)	L=	152.4	cm
(Temps à h/ho = 0,37)	To=	8.7	s





$$K = \frac{r^2 \ln(L/r)}{2 * L * To}$$

Conductivité hydraulique

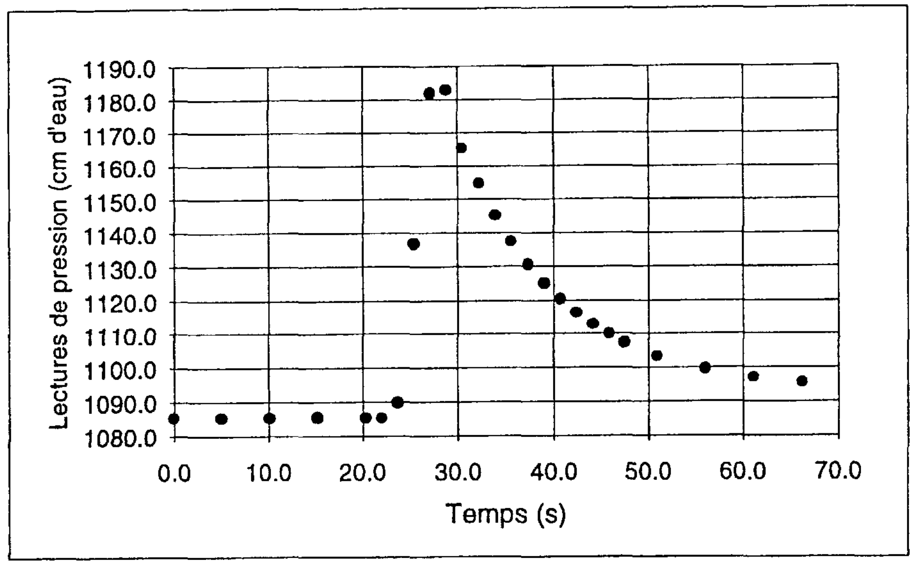
K= 1.0E-02 cm/s

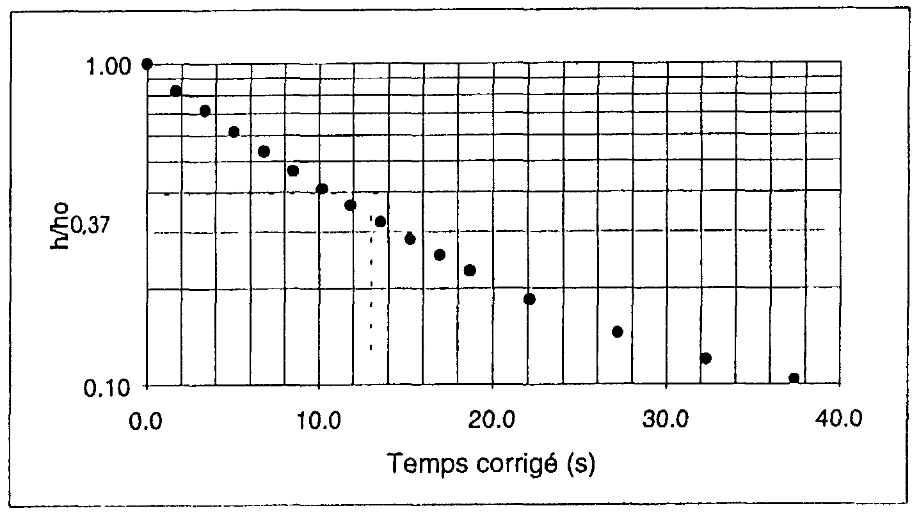
Figure 10. Essai de perméabilité à niveau descendant, puits P7a

Temps (s)	Pression (cm d'eau)	h (cm)	Temps corr. (s)	h/ho
0.0	1085.2	0.00	-28 8	0.00
5.0	1085.2	0 00	-23.8	0 00
10.1	1085.3	0.10	-18.7	0.00
15.2	1085.4	0 20	-13.6	0.00
20.3	1085 3	0 10	-8.5	0 00
22.0	1085.2	0.00	-6.8	0.00
	Injection d'eau			
23.7	1089.6	4.40	-5.1	0.05
25 4	1136.8	51.60	-3.4	0 53
27.1	1181.8	96.60	-1.7	0.99
	Début de l'essai			
28.8	1182.7	97.50	0.0	1.00
30.5	1165.2	80.00	1.7	0.82
32.2	1154.7	69 50	3.4	0.71
33.9	1145 1	59.90	5.1	0.61
35.6	1137.2	52.00	6.8	0.53
37.3	1130 5	45.30	8 5	0.46
39.0	1125.0	39.80	10.2	0 41
40.7	1120.4	35.20	11.9	0.36
42.4	1116.3	31.10	13.6	0.32
44 1	1112.8	27.60	15 3	0.28
45.8	1109.8	24.60	17.0	0 25
47.5	1107.2	22.00	18.7	0.23
50.9	1103.1	17.90	22.1	0.18
56.0	1099.3	14.10	27.2	0.14
61.1	1096.8	11.60	32.3	0 12
66.2	1095.3	10 10	37.4	0 10

Calibration

	ho=	97.5	cm
(Rayon du puits)	r=	2.54	cm
(Long. crépine)	L=	152.4	cm
(Temps à h/ho = 0,37)	To=	12.3	s





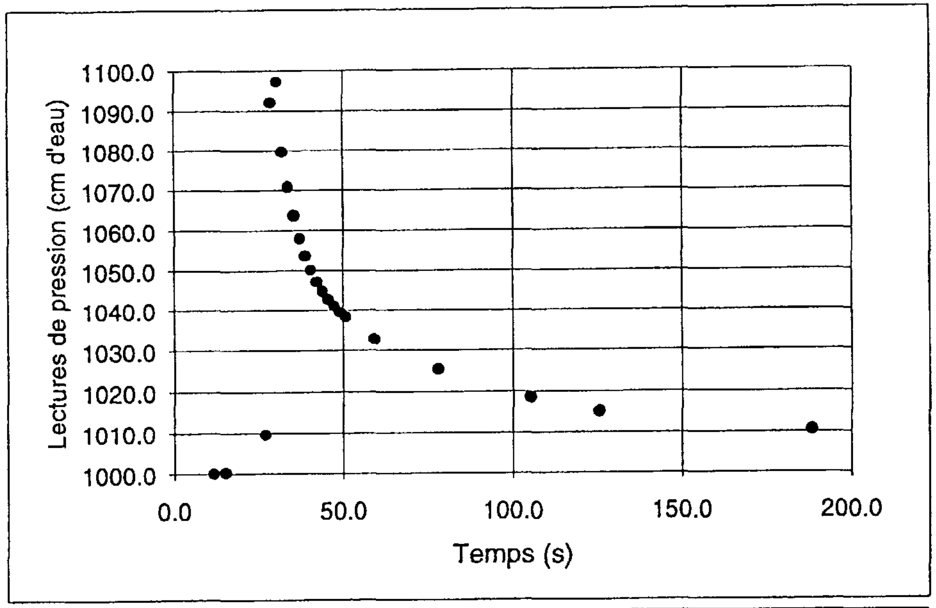
$$K = \frac{r^2 \ \ln (L/r)}{2^*L^*To}$$

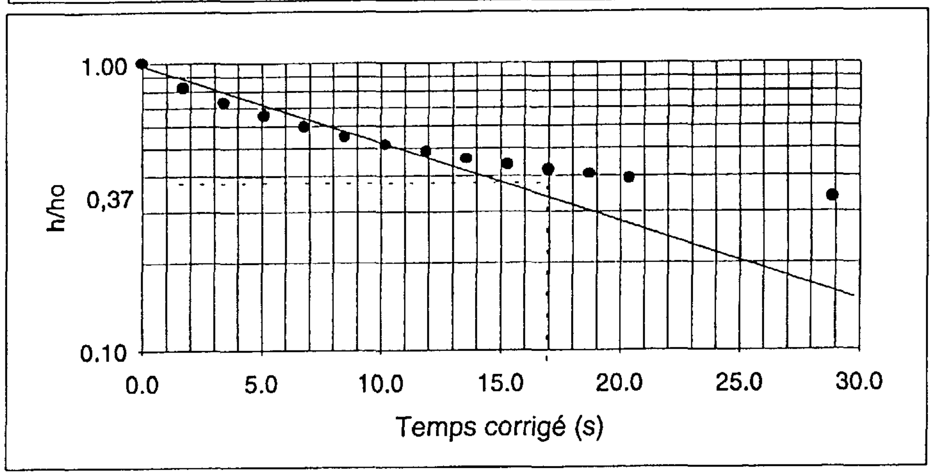
Conductivité hydraulique

K= 7.1E-03 cm/s

Figure 11. Essai de perméabilité à niveau descendant, puits P8a

Temps (s)	Pression (cm d'eau)	h (cm)	Temps corr. (s)	h/ho	
0.0	998.9	-1.30	-30.5	-0.01	Calibration
11.8	999.9	-0.30	-18.7	0.00	
15.2	1000.2	0.00	-15.3	0.00	
	Injection d'eau				
27.1	1009.5	9.30	-3.4	0.10	
28.8	1091.9	91.70	-1.7	0 95	
	Début de l'essai				
30.5	1097.1	96.90	0.0	1.00	
32.2	1079.4	79.20	1.7	0.82	
33 9	1070.7	70.50	3.4	0.73	
35.6	1063.6	63.40	5 1	0.65	
37.3	1057.9	57.70	6 8	0.60	
39 0	1053.4	53 20	8.5	0 55	
40.7	1049.9	49.70	10.2	0.51	
42.4	1047.0	46.80	11 9	0.48	
44.1	1044.6	44.40	13.6	0.46	
45 8	1042.6	42.40	15.3	0.44	
47.5	1040.9	40.70	17.0	0.42	
49 2	1039.4	39.20	18.7	0.40	
50 9	1038.0	37 80	20.4	0.39	
59.4	1032.6	32.40	28.9	0.33	
78 1	1025.2	25.00	47.6	0.26	
105.3	1018.3	18.10	74.8	0.19	
125.7	1014.9	14.70	95.2	0.15	
188.6	1010.3	10.10	158.1	0.10	





	ho=	96.9	cm
(Rayon du puits)	r=	2.54	cm
(Long. crépine)	L=	152.4	cm
(Temps à h/ho = 0,37)	To=	15.8	s

$$K = \frac{r^2 \ \ln (L/r)}{2^*L^*To}$$

Conductivité hydraulique

K= 5.5E-03 cm/s

Figure 12. Essai de perméabilité à niveau descendant, Puits P8b

APPENDIX 3.

Table of d_{10} and hydraulic conductivity calculated from grain-size curves

Sample no. (depth in feet)	d_{10} (mm)	Hydraulic conductivity (m/s)
P-1 (5-10)	8.90×10^{-2}	7.92×10^{-5}
P-1 (20-25)	6.50×10^{-2}	4.23×10^{-5}
P-1 (40-45)	1.04×10^{-1}	1.08×10^{-4}
P-2 (22.5-25)	2.70×10^{-2}	7.29×10^{-6}
P-2 (40-45)	9.60×10^{-2}	9.22×10^{-5}
P-3 (15-20)	7.60×10^{-2}	5.78×10^{-5}
P-3 (40-45)	2.70×10^{-2}	7.29×10^{-6}
P-4 (5-10)	9.90×10^{-2}	9.80×10^{-5}
P-4 (25-30)	5.70×10^{-2}	3.25×10^{-5}
P-4 (40-45)	1.07×10^{-1}	1.14×10^{-4}
P-5 (10-15)	8.90×10^{-2}	7.92×10^{-5}
P-5 (25-30)	8.00×10^{-2}	6.40×10^{-5}
P-5 (40-45)	1.40×10^{-2}	1.96×10^{-6}
P-6 (5-10)	1.02×10^{-1}	1.04×10^{-4}
P-6 (25-30)	1.00×10^{-2}	1.00×10^{-6}
P-6 (30-35)	7.40×10^{-2}	5.48×10^{-5}
P-7 (15-20)	1.30×10^{-2}	1.69×10^{-6}
P-7 (25-30)	1.04×10^{-1}	1.08×10^{-4}
P-8 (15-20)	8.00×10^{-3}	6.40×10^{-7}
P-8 (25-30)	5.80×10^{-2}	3.36×10^{-5}
Mean hydraulic conductivity		2.5×10^{-5}

APPENDIX 4

Records of boreholes

PROJECT: 952-6384

LOCATION: Dundurn

DIP:

RECORD OF BOREHOLE P1

BORING DATE: TUE NOV 14/95

SAMPLER HAMMER, kg, DROP, mm

SHEET 1 OF 1

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	RECOVERY %	LAB TESTING	INSTALLATIONS
		Ground Surface		512.13						
0	Earth Drilling Brat 22, Hollow Stem Auger	SANDY TOPSOIL-thin layer, trace rootlets, dark brown/light black		0.02						
1		SAND-light brown, damp, fine grained			1	DO		80		Bentonite Seal
2		- layered grey and brown - trace Fe staining			2	DO		65		
4		- Fe staining at 4 m - salts			3	DO		67		
5					4	DO		60		Grout
7		- water at 7.01 m			5	DO		73		
8					6	DO		53		
10		~ trace coal fragments at 10 m			7	DO		90		12 20 Frac Sand
11					8	DO		65		
13					9	DO		68		
14					10	DO		65		
15				496.89 15.24						

GAS CONCENTRATION ( ) % LEL

HYDRAULIC CONDUCTIVITY k, cm/s

WATER CONTENT, PERCENT Wp W Wl

INSTALLATIONS: A B 3

DATA INPUT AL

DEPTH SCALE (ALONG HOLE) 1 to 100

Golder Associates

LOGGED: A.L.

CHECKED:

RECORD OF BOREHOLE P2

PROJECT: 952-6384
LOCATION: Dundurn
DIP:

BORING DATE: Wed Nov 15/95
SAMPLER HAMMER, kg; DROP, mm

SHEET 1 OF 1
DATUM: Geodetic

Boring method: Earth Drilling Brat 22, Hollow Stem Auger

DEPTH SCALE METRES	DESCRIPTION	ELEV / DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RECOVERY %	LAB TESTING
0	Ground Surface	511.62					
0–1	SAND-light brown, frozen to 0.6 m, damp, fine grained		1	DO		67	
1	-thin 0.02 m organic layer at 1 m						
2			2	DO		90	
3–4	-Fe staining starts at 3 66 m -grey at 3 66 m -moister		3	DO		98	
5–6	-layered at 5.49-6 1m -dark grey sand lense at 5.49m		4	DO		90	
6–7	-water at 6 4m -layered at 6.55m -thin silt seams and coal seams		5	DO		100	
8	-trace coal fragments on free water in sample		6	DO		57	
10			7	DO		97	
11			8	DO		85	
13			9	DO		80	
14			10	DO		17	
15		496.38 15.24					

GAS CONCENTRATION ( ) — % LEL
HYDRAULIC CONDUCTIVITY k, cm/s
WATER CONTENT PERCENT Wp — W — Wl

INSTALLATIONS

A B

Bentonite Seal

Grout

Bentonite Seal

12-20 Frac Sand

DEPTH SCALE (ALONG HOLE)
1 to 100

Golder Associates

LOGGED: A.L.
CHECKED:

DATA INPUT AL

RECORD OF BOREHOLE P3

PROJECT: 952-6384
LOCATION: Dundurn
DIP.

BORING DATE: Wed Nov 15/95
SAMPLER HAMMER, kg; DROP, mm

SHEET 1 OF 1
DATUM. Geodetic

DEPTH SCALE METRES	BORING METHOD	DESCRIPTION	ELEV / DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RECOVERY %	INSTALLATIONS
		Ground Surface	511.01 / 0.00					
0–1	Earth Drilling Brat 22 Hollow Stem Auger	SAND-light brown, frozen to 0.6 m, damp, fine grained		1	DO		70	Bentonite Seal
2				2	DO		78	
3–4				3	DO		87	Grout
4–5		-Fe staining at 4.27m -small piece of wood at 4.57m		4	DO		87	
6–7		-coarser sand at 5.64 m -layering at 5.79m -water at 6.4m		5	DO		85	
7–8		-black streaking at 7.32m		6	DO		73	Slough Sand
9–10		-0.051 m coal layer at 8.84m - finer sand to depth -trace coal particles floating on free water on samples to depth		7	DO		72	Bentonite Seal
11				8	DO		100	12-20 Frac Sand
13			487.29 / 13.72	9	DO		100	

GAS CONCENTRATION ( ) ● ; % LEL □
HYDRAULIC CONDUCTIVITY, k, cm/s
WATER CONTENT, PERCENT Wp W Wl
LAB TESTING ; STRATA PLOT

INSTALLATIONS A B 3

DATA INPUT AL

DEPTH SCALE (ALONG HOLE) 1 to 100

Golder Associates

LOGGED: A.L.
CHECKED:

PROJECT: 952-6384

LOCATION. Dundurn

DIP:

RECORD OF BOREHOLE P4

BORING DATE: Thur Nov 16/95

SAMPLER HAMMER, kg; DROP, mm

SHEET 1 OF 1

DATUM: Geodetic

SOIL PROFILE

Boring method: Earth Drilling Brat 22 / Hollow Stem Auger

Depth scale (metres)	Description	Elev / Depth (m)
	Ground Surface	511.23 / 0.00
0–15.24	SAND-brown, damp, fine grained -Fe staining at 2.44m -finer sand -Fe staining at 3.81m -salts at 3.96m -black streaking at 3 66 and 4 27m -sand moist at 5 64m -water at 6 5m -black streaks from 6.55 to 7 32m -reddish free water at 7 01 to 7.62m -alternating thin layering of sand and coal seams -coarser sand at 8 69 to 8.84m -coal fragments floating on free water in samples	495 99 / 15 24

SAMPLES

Number	Type	Blows/0.3m	Recovery %	Lab Testing
1	DO		67	
2	DO		100	
3	DO		97	
4	DO		97	
5	DO		97	
6	DO		65	
7	DO		73	
8	DO		97	
9	DO		90	
10	DO		68	

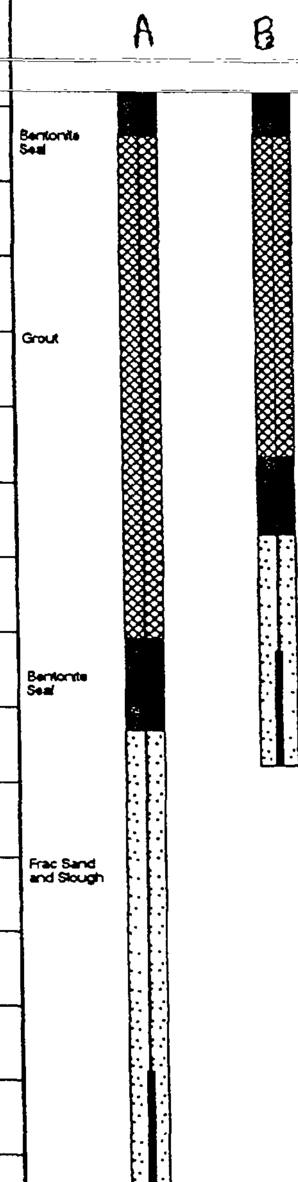
GAS CONCENTRATION ⊕ ( )

% LEL □

HYDRAULIC CONDUCTIVITY, k, cm/s

WATER CONTENT PERCENT Wp W Wl

INSTALLATIONS



3

DATA INPUT AL

DEPTH SCALE (ALONG HOLE)

1 to 100

Golder Associates

LOGGED: A.L.

CHECKED:

PROJECT: 952-6384

RECORD OF BOREHOLE P5

SHEET 1 OF 1

LOCATION: Dundum

BORING DATE: Fri Nov 24/95

DATUM: Geodetic

DIP:

SAMPLER HAMMER, kg; DROP, mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	RECOVERY %	LAB TESTING	INSTALLATIONS
		Ground Surface		511.51						
0	Earth Drilling Brat 22 Hollow Stem Auger			0.00						Bentonite Seal
1		SAND-light brown, damp, fine grained -dark grey streaks at 1.07m			1	DO		77		
2		-0.08m organic layer at 1.83m -Fe staining 1.98m to 2.59m			2	DO		100		
3										Grout
4		-black streaks from 4.11m to 4.57m			3	DO		90		
5					4	DO		95		
6		-layered black/brown/grey -0.025m black seam at 5.94m								
7		-water at 6.71m -black streaking from 6.4 to 7.62m			5	DO		90		
8					6	DO		85		Bentonite Seal
9		-layering of sand and coal seams at 8.7 m -black streaks at 8.94 m -fine grey sand at 9 m (unoxodized)								
10					7	DO		75		12-20 Sand and Slough
11					8	DO		97		
12										
13					9	DO		95		
14					10	DO		83		
15				496.27 15.24						
16										
17										
18										
19										
20										

GAS CONCENTRATION ( ) — % LEL

HYDRAULIC CONDUCTIVITY, k, cm/s — WATER CONTENT, PERCENT Wp W Wl

INSTALLATIONS: A B

3

DATA INPUT AL

DEPTH SCALE (ALONG HOLE) 1 to 100

Golder Associates

LOGGED: A.L

CHECKED:

PROJECT: 952-6384

LOCATION: Dundurn

DIP:

RECORD OF BOREHOLE P6

BORING DATE: Fri Nov 24/95

SAMPLER HAMMER, kg; DROP, mm

SHEET 1 OF 1

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	DESCRIPTION	STRATA PLOT	ELEV / DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	RECOVERY %	LAB TESTING
		Ground Surface		511.42					
0	Earth Drilling Brat 22 / Hollow Stem Auger			0.00					
1		SAND-light brown, damp, fine grained, uniform			1	DO		70	
2					2	DO		42	
3									
4		-Fe staingin from 3 to 4.5m			3	DO		35	
5					4	DO		43	
6		-water between 5.2 and 6 1m							
7		-water at 6 71m			5	DO		100	
8		-coal layers and coarser sand from 7.5 to 7.62m			6	DO		43	
9		-trace Fe staining from 8 84 to 9.14m							
10		-trace coal particles floating on free water on sample			7	DO		50	
11					8	DO		0	
12									
13					9	DO		0	
				497.70 / 13.72					
14									
15									
16									
17									
18									
19									
20									

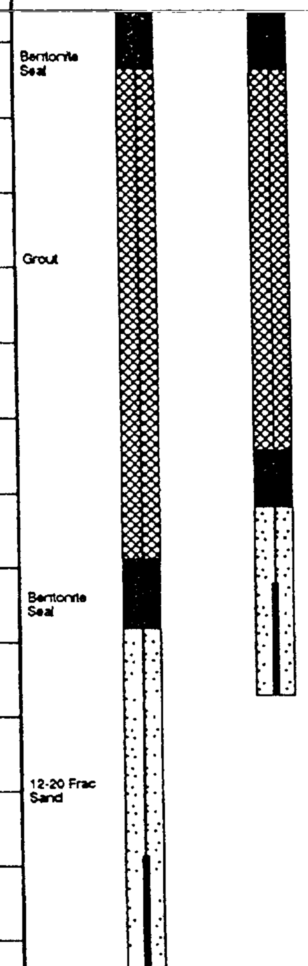
GAS CONCENTRATION ( ) ⊕ % LEL □

HYDRAULIC CONDUCTIVITY, k, cm/s

WATER CONTENT PERCENT Wp —○W— Wl

INSTALLATIONS

A B 3



DATA INPUT AL

DEPTH SCALE (ALONG HOLE)

1 to 100

Golder Associates

LOGGED: A.L

CHECKED:

PROJECT: 952-6384

LOCATION: Dundum

DIP:

RECORD OF BOREHOLE P7

BORING DATE: Sat Nov 25/95

SHEET 1 OF 1

DATUM: Geodetic

SAMPLER HAMMER, kg; DROP, mm

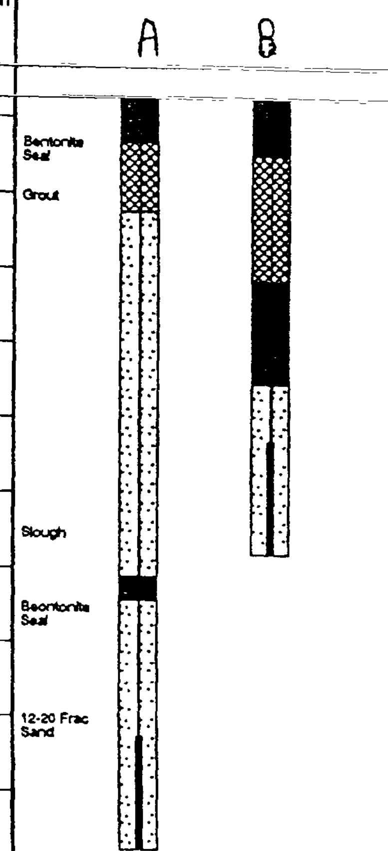
DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE – DESCRIPTION	STRATA PLOT	ELEV / DEPTH (m)	SAMPLES – NUMBER	TYPE	BLOWS/0.3m	RECOVERY %	LAB TESTING
0		Ground Surface		510.27 / 0.00					
1	Earth Drilling Brat 22 / Hollow Stem Auger	SAND-light brown, damp, fine grained			1	DO		53	
1–2		-Fe staining from 1.22 to 1.37m -black streak at 1.37m			2	DO		38	
4		-water at 4.27m			3	DO		83	
5–6		-unoxodized at 5.64m -black streaks at 5.49m and 5.79m -Fe staining at 5.79m			4	DO		63	
7					5	DO		12	
8					6	DO		52	
10				499.60 / 10.67	7	DO		78	

GAS CONCENTRATION ( ) ⊕ — % LEL □

HYDRAULIC CONDUCTIVITY, k, cm/s

WATER CONTENT, PERCENT Wp —○W— Wl

INSTALLATIONS



DATA INPUT AL

DEPTH SCALE (ALONG HOLE)

1 to 100

Golder Associates

LOGGED: A.L

CHECKED:

PROJECT: 952-6384

LOCATION: Dundum

DIP:

RECORD OF BOREHOLE P8

BORING DATE: Sat Nov 25/95

SAMPLER HAMMER, kg; DROP, mm

SHEET 1 OF 1

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	RECOVERY %	LAB. TESTING	INSTALLATIONS
		Ground Surface		509.06						
0				0.00						Bentonite Seal
1		SAND-light brown, damp, fine grained, Fe stained,			1	DO		62		
2		-decreasing Fe staining with depth			2	DO		52		Grout
4		-water at 4.57m			3	DO		52		Bentonite Seal
5	Earth Drilling Brat 22 / Hollow Stem Auger	-layering at 4.88m			4	DO		52		
7					5	DO		48		12-20 Frac Sand
8		-coal specks on free water from samples			6	DO		100		
10				498.39 / 10.67	7	DO		100		

GAS CONCENTRATION ( ) % LEL

HYDRAULIC CONDUCTIVITY k, cm/s

WATER CONTENT, PERCENT Wp W Wl

INSTALLATIONS A B

3

DATA INPUT: AL

DEPTH SCALE (ALONG HOLE) 1 to 100

Golder Associates

LOGGED: A.L.

CHECKED:

APPENDIX 5.

TNT, RDX and HMX analysis in soil samples

FORAGE DURDUN AUTOMNE 1995

ECHANTILLON	RDX		TNT		HMX
	DTECH	8330	DTECH	8330	8330
P1 5-10	LOW (352)	-	LOW (314)	-	-
P1 10-15	LOW (348)	nd	LOW (302)	nd	0,4
P1 15-20	LOW (327)	-	LOW (282)	-	-
P1 20-25	LOW (360)	nd	LOW (320)	nd	nd
P1 25-30	LOW (347)	-	LOW (307)	-	-
P1 30-35	LOW (361)	nd	LOW (245) 1% (247)	0,3	nd
P1 35-40	LOW (354)	-	LOW (249)	-	-
P1 40-45	LOW (336)	-	LOW (247)	-	-
P1 45-50	LOW (336)	nd	2% (243)	0,2	nd

FORAGE DURDUN AUTOMNE 1995

ECHANTILLON	RDX		TNT		HMX
	DTECH	8330	DTECH	8330	8330
P2 0-5	LOW (351)	nd	3% (236) 2% (230)	nd	nd
P2 5-10	LOW (350)	-	LOW (260)	-	-
P2 10-15	LOW (351)	nd	LOW (246)	nd	nd
P2 15-20	LOW (336)	-	1% (251)	-	-
P2 20-22.5	LOW (347)	nd	1% (233)	nd	nd
P2 22.5-25	LOW (349)	nd	LOW (251) LOW (241)	nd	nd
P2 25-27'8"	LOW (346)	-	LOW (286)	-	-
P2 25-30	LOW (360)	nd	3% (276)	nd	nd
P2 30-35	LOW (372)	-	LOW (293)	-	-
P2 35-40	LOW (381)	nd	3% (230)	0,4	nd
P2 40-45	LOW (360)	-	LOW (320)	-	-

ECHANTILLON	RDX		TNT		HMX
	DTECH	8330	DTECH	8330	8330
P3 0-5	LOW (350)	nd	LOW (248)	nd	nd
P3 5-10	LOW	-	LOW	-	-
P3 10-15	LOW (375) LOW (352)	nd	LOW (262) LOW (249)	nd	nd
P3 15-20	LOW (357)	-	2% (249)	-	-
P3 20-25	LOW (358)	nd	LOW (254)	nd	nd
P3 25-30	LOW (362)	-	LOW (250)	-	-
P3 30-35	LOW (366)	nd	LOW (254)	nd	nd
P3 35-40	LOW (357)	-	1% (242)	-	-
P3 40-45	LOW (343)	nd	LOW (250)	nd	nd
P3 45-50	LOW (346)	-	8% (248)	-	-

FORAGE DURDUN AUTOMNE 1995

ECHANTILLON	RDX		TNT		HMX
	DTECH	8330	DTECH	8330	8330
P4 0-5	LOW (351)	nd	LOW (254)	nd	nd
P4 5-10	LOW (352)	-	LOW (247)	-	-
P4 10-15	LOW (350)	nd	LOW (252)	nd	nd
P4 15-20	LOW (362)	-	LOW (241)	-	-
P4 20-25	LOW (365)	nd	LOW (247)	nd	nd
P4 25-30	LOW (362)	-	LOW (249)	-	-
P4 30-35	LOW (355)	nd	1% (202)	1,0	0,4
P4 35-40	LOW (355)	-	LOW (217)	-	-
P4 40-45	LOW (343)	1,3	3% (243)	0,8	nd
P4 45-50	LOW (345)	-	1% (201)	-	-

FORAGE DURDUN AUTOMNE 1995

ECHANTILLON	RDX		TNT		HMX
	DTECH	8330	DTECH	8330	8330
P5 0-5	LOW (335)	nd	5% (231)	nd	nd
P5 5-10	LOW (339)	-	1% (220)	-	-
P5 10-15	LOW (341)	nd	LOW (246)	nd	nd
P5 15-20	LOW (326)	-	LOW (259)	-	-
P5 20-25	LOW (278)	nd	1% (231)	nd	nd
P5 25-30	LOW (300)	-	LOW (246)	-	-
P5 30-35	LOW (273)	nd	LOW (252)	nd	nd
P5 35-40	LOW (320)	-	LOW (276)	-	-
P5 40-45	LOW (388)	nd	LOW (241)	nd	nd
P5 45-50	LOW (388)	-	LOW (243)	-	-

ECHANTILLON	RDX		TNT		HMX
	DTECH	8330	DTECH	8330	8330
P6 0-5	LOW (367)	nd	LOW (267)	nd	nd
P6 5-10	LOW (386)	-	5% (243)	-	-
P6 10-15	LOW (352)	nd	LOW (279)	nd	nd
P6 15-20	LOW (349)	-	6% (250)	-	-
P6 20-25	LOW (334)	nd	LOW (241)	nd	nd
P6 25-30	LOW (334)	-	2% (234)	-	-
P6 30-35	LOW (351)	nd	4% (238)	nd	nd

FORAGE DURDUN AUTOMNE 1995

ECHANTILLON	RDX		TNT		HMX
	DTECH	8330	DTECH	8330	8330
P7A 0-5	LOW (354)	nd	LOW (220)	nd	nd
P7A 5-10	LOW (351)	-	2% (228)	-	-
P7A 10-15	LOW (354)	nd	LOW (258)	nd	nd
P7A 15-20	LOW (360)	-	4% (247)	-	-
P7A 20-25	LOW (335)	nd	LOW (262)	nd	nd
P7A 25-30	LOW (353)	-	LOW (291)	-	-
P7A 30-35	LOW (347)	nd	LOW (341)	nd	nd

ECHANTILLON	RDX		TNT		HMX
	DTECH	8330	DTECH	8330	8330
P8B 5-10	LOW (372)	nd	1% (248)	nd	nd
P8B 15-20	LOW (362)	-	LOW (250)	-	-
P8B 25-30	LOW (403)	nd	2% (245)	nd	nd

APPENDIX 6

TNT, RDX and HMX analysis in groundwater samples

ÉCHANTILLONS	DATE	[RDX]	[TNT]	[HMX]
		ppb ± 0,2	ppb ± 0,2	ppb ± 0,2
P1A	nov-95	5,3	2	<0,3
P1A	avr-96	4,9	<0,3	<0,3
P1B	nov-95	5,1	<0,3	2,2
P1B	avr-96	3,6	<0,3	<0,3
P2A	nov-95	0,8	1,6	<0,3
P2A	avr-96	0,5	<0,3	<0,3
P2B	nov-95	1,7	<0,3	<0,3
P2B	avr-96	<0,3	<0,3	<0,3
P3A	nov-95	5,6	<0,3	5,7
P3A	avr-96	3,4	<0,3	2,9
P3B	nov-95	77,9	2,7	0,9
P3B	avr-96	120,8	1,9	0,9
P4A	nov-95	2,8	<0,3	1,1
P4A	avr-96	2,0	<0,3	1,1
P4B	nov-95	5,8	<0,3	<0,3
P4B	avr-96	3,0	<0,3	<0,3
P5A	nov-95	1,4	<0,3	<0,3
P5A	avr-96	0,9	<0,3	<0,3
P5B	nov-95	non échant.	non échant.	non échant.
P5B	avr-96	<0,3	<0,3	<0,3
P6A	nov-95	1,3	<0,3	<0,3
P6A	avr-96	<0,3	<0,3	<0,3
P6B	nov-95	2,0	2,4	<0,3
P6B	avr-96	<0,3	<0,3	<0,3
P7A	nov-95	<0,3	<0,3	<0,3
P7A	avr-96	<0,3	<0,3	<0,3
P7B	nov-95	1,8	<0,3	1,2
P7B	avr-96	<0,3	<0,3	<0,3
P8A	nov-95	<0,3	<0,3	<0,3
P8A	avr-96	<0,3	<0,3	<0,3
P8B	nov-95	<0,3	<0,3	<0,3
P8B	avr-96	<0,3	<0,3	<0,3

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